Relationships between nasal cavity function and maxillofacial morphology among children with malocclusion in the growth and development stage

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成長発育期の不正咬合者における鼻腔機能と顎顔面形態との関連性について

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Abstract

A decrease in olfactory function can put an individual's life at risk by, for example, rendering them vulnerable to consume rotten food, or to fail to notice gas leaks or fires sufficiently early to escape. Nevertheless, there have been few clinical studies examining olfaction and, in particular, we were unable to find any clinical studies examining olfaction in children.

Accordingly, the objective of the present study was to clarify the relationships between nasal cavity functions and maxillofacial morphology among children with malocclusion in the growth stage.

Subjects in this study included 68 patients (30 boys, 38 girls; mean age 9.3±1.6 years [range 6-12 years] who were examined at the Department of Orthodontics at Ohu

University Hospital. Based on the skeletal classification described by Utsuno et al. [5], there were 22 patients in the skeletal class I group (2° ≦ A point, nasion, B point [ANB] ≦ 4°), 24 in the skeletal class II group (ANB > 4°), and 22 in the skeletal class III group (ANB < 2°). By referring to an article on otorhinolaryngology and head and neck surgery,[6] the patients were asked about their olfactory disorders.

We performed maxillofacial measurements and olfactory tests to clinically investigate relationships between nasal cavity functions and maxillofacial morphology among individuals with malocclusion in the growth and development stage. The results demonstrated that less maxillary growth was associated with reduced olfaction in children with malocclusion from skeletal mandibular

protrusion. This suggests that maxillary growth and development is related to olfaction.

As orthodontists, we perform orthodontic therapy on children during their growth and development stage. Improving their maxillofacial morphology may improve their olfactory functions. In the future, we plan to investigate how malocclusion therapy impacts olfactory functions.

抄録

不正咬合と呼吸機能に関する報告は数多く行われているが，鼻腔機能の一つである嗅覚との関連性についての報告はない。本研究では，成長発育期における不正咬合者の鼻腔機能と顎顔面形態について検討した。

奥羽大学歯学部附属病院矯正歯科を受診し，検査の同意が得られた68名（平均年齢9.3±1.6歳，男児30名，女児38名）のSkeletal I群22名（2°≦ANB≦4°），Skeletal II群24名（ANB＞4°）およびSkeletal III群22名(ANB＜2°)不正咬合者を対象とした。嗅覚障害の有無を問診にて評価し，嗅覚障害の可能性がある者は対象から除外した。顎顔面形態は，側面セファログラムおよび平行模型の計測を行った。鼻腔機能は，鼻腔通気度検査と嗅覚検査の測定にて評価した。鼻腔通気度検査は，アンテリオール法にて鼻腔通気度測定装置で測定した。また，

嗅覚検査は，基準嗅覚検査を用いて嗅覚感度を評価した。ニオイを感じた値（検知閾値）とどのようなニオイか認知した値（認知閾値）を測定した。統計処理は，顎顔面形態，嗅覚，平行模型，鼻腔通気度を Skeletal I,II,III 群不正咬合者の間で Kruskal-Wallis test を行った結果を，多重比較で Mann-Whitney U-test を用いて比較し，顎顔面形態と嗅覚の関連を Spearman の順位相関係数で解析した。有意水準は $p<0.05$ に設定した。

顎顔面形態では，Skeletal III 群は，他の群と比較して SNA 角および上顎骨歯槽長径が有意に小さい値を示した。嗅覚検査結果では，Skeletal III 群は他の群に比べて検知閾値（<.05）および認知閾値（<.05）ともに有意に高い値を示した。さらに，鼻腔通気度検査では、変化率に有意な差を認めなかった。この結果より Skeletal III 群では，吸気量に変化がないにも関わらず，嗅覚が低下していた。顎顔

面形態と嗅覚との相関では，SNAと認知閾値（r ＝ −0.498），McNamara to Aと認知閾値（r＝−0.529）ともに，低い負の相関が認めたことから，顎顔面形態と嗅覚に関連があると考えられた。成長発育期の不正咬合者では，鼻腔機能と顎顔面形態との間で関連性があることが示唆された。

INTRODUCTION

Since 1991, there have been several investigations reported in the field of cranial neurology; however, many areas within the field remain less extensively examined.[1,2)] It is well known that humans can distinguish among thousands of different scents; however, it remains unclear which specific olfactory neural receptors are involved in differentiating smell, and it is particularly difficult to identify them physiologically. Recently, Axel and Buck identified genes that encode olfactory receptor information, and there has been progress in basic research investigating olfaction.[1)]

Problems in olfactory function may result in life-threating situations such as consuming spoiled food, not noticing gas leaks, and failure to escape from fire.

Nevertheless, there have been only a few clinical studies examining olfaction in particular and, to our knowledge, there is no previous clinical report investigating olfaction in children.

Surveys involving children with impaired olfactory function have not been performed because the priority is lower than that of other sensory systems, such as sight and hearing, and there is usually no significant impact on daily life.[3)]

Hummel et al.[4)] reported that in the case of left-right differences in olfactory bulb volume, the smaller the volume the higher the thresholds. Therefore, to clarify the relationships between nasal cavity functions and maxillofacial morphology among children with malocclusion in the growth stage, we hypothesized that

abnormalities in maxillofacial morphology during the growth and development stage would influence olfaction.

MATERIALS AND METHODS

I. Materials

This study was approved by the Ethics Screening Committee of Ohu University (Kōriyama, Japan, No. 139). Subjects in this study included 68 patients (30 boys, 38 girls; mean age 9.3±1.6 years [range 6-12 years]) who were examined at the Department of Orthodontics at Ohu University Hospital. Informed consent for the examination was obtained from the subjects and their guardians. Based on the skeletal malocclusion classification described by Utsuno et al.,[5] there were 22 patients in skeletal class I (2° ≦ A point, nasion, B point [ANB] ≦ 4°), 24 in

skeletal class II (ANB > 4°), and 22 in skeletal class III (ANB < 2°). Based on an article on otorhinolaryngology and head and neck surgery,[6] the guardians were asked about their olfactory disorders. Guardians in whom any of the following applied were excluded: nasal disease (including history of common cold in the past 3 months); those found to have nasal polyps, nasal tumors, drug-induced or iron-deficiency anemia, undergone radiation therapy, experienced trauma or surgery to the sinuses or nasal cavity, or received general anesthesia; deviated septum found during observation of the nasal cavity with a mirror or frontal cephalogram history of adenoidectomy or tonsillectomy; and cleft lip and palate, congenital diseases, or an abnormal number of teeth.

II. Measuring maxillofacial morphology

Assessments of maxillofacial morphology were performed by the same assessor, who measured models of the oral cavity and traced lateral cephalograms, then used software for measuring the cephalographic data (Dolphin imaging software version 11.9, Dolphin Imaging Systems, LLC, Chatsworth, CA, USA) to designate measurement points following the method described by Thompson[7] (Figure 1) for measuring lines and angles.

Lateral cephalogram imaging conditions: Measurements were performed using lateral cephalograms taken at the initial examination. The imaging conditions for lateral cephalograms were as follows: patients were in a standing position with the Frankfort plane parallel to the floor; the

mandible was in the intercuspal position; the lips were closed; the tongue was in a resting position; patients were at rest and their respiration was not regulated.

Dental cast measurements: Measurements were performed according to methods described by Howes et al.[8] and Berger[9] using dental cast obtained at the initial examinations. Basal arch width was measured as the distance between the points of greatest buccolingual depression at a location equivalent to the root apex on the buccal side of the alveolus on both first molars. Basal arch length was measured using the instrument described by Otsubo et al.[10] The posterior margin of the base of the instrument was made to conform to the distance between the pit and grooves of both first molars. The measurement was

performed by aligning the needle with the point of greatest depression at a location equivalent to the root apex of the labial alveolar area of the left central incisor (proximal limit of the alveolar base) (Figure 2).

III. Nasal cavity functions

Olfactory test: This study used a T&T olfactometer® following the method described by Kawasaki et al.[11] to perform standard olfactory tests. The tests were performed using designated reagents according to manufacturer's recommendations (Daiichi Yakuhin Sangyo Ltd., Tokyo). Five scents were used in the test to measure detection and recognition thresholds: A (β-phenylethyl alcohol); B (methyl cyclopentenolone); C (iso-valeric acid); D (γ-undecalactone); and E (skatole).

The detection threshold was determined by having patients initially smell samples at low concentrations, then raising the concentration incrementally. The detection threshold was the concentration at which a scent was sensed. The recognition threshold was determined by further increasing the concentration until the type of scent was identified.

Olfaction measurements were performed by an assessor holding one end of a piece of scent paper (7 mm wide × 15 cm long) and immersing 1 cm of the other end in a standard scent. The scent paper was then handed to the patient, who held the end of the paper approximately 1 cm from the tip of the nose to assess it by smell. The sequence of the test was to increase the concentration of the standard scents (minus 2 – plus 5) from low to high. The degree of plus 5 is

the highest concentration and the strongest scent. A concentration of each degree increases 10 times each. The patient was asked when he perceived the standard scent, and the concentration of the number by 10 this scent was recorded on an olfactogram (detection threshold). The concentration was then increased further and, when the patient could correctly identify the type of the standard scent, this was recorded on the olfactogram (recognition threshold). If a patient could not identify a scent, the answers listed in Table 2 were offered and the patient selected the scent that applied.

Mean values for the detection and recognition thresholds for scents A to E were calculated based on the detection and recognition thresholds recorded on the olfactograms used in the above measurements. Then, olfaction was

assessed as normal or reduced according to 5 grades based on the criteria listed in Table 3. The mean recognition threshold better reflects an individual's actual life circumstances than the mean detection threshold; consequently, the former was adopted for the assessments.

Rhinomanometry: Rhinomanometry was performed using a multifunctional spirometer (HI-801, CHEST M.I. Inc, Tokyo, Japan), which is the testing method adopted from the rhinomanometry guidelines from the Japanese Rhinologic Society.[12] Measurements of the left and right sides were performed using the mask-anterior method, in which the posterior pressure of the nasal cavity is derived from the anterior nostril of the side not being measured. Bilateral nasal cavity resistance was calculated from the

right and left resistance values using Ohm's law equation ($1/T = 1/R + 1/L$, T: both nostrils, R: right resistance, L: left resistance). Before the measurements, the patients were instructed to rest in a sitting position with the head in a natural position. During the measurements, subjects were instructed to close their mouths and breathe through the nose. In this study, measurement results of inspiration were used.

Nasal cavity resistance was expressed as $Pa/cm^3/s$. Following the Japanese Committee for Standardizing Rhinomanometry, $\Delta P100Pa$ was adopted as the resistance value.

IV. Statistics

Statistical analyses were performed using SPSS version 24.0 (IBM Corporation, Armonk, NY, USA). Comparisons of maxillofacial morphology, olfaction, oral cavity models, and rhinomanometry among the skeletal class I, II, and III malocclusion groups were performed using the Kruskal-Wallis test. Multiple comparisons of these results were performed using the Mann-Whitney U test. Correlations between maxillofacial morphology and olfaction were analyzed using Spearman's rank correlation coefficient; $p < 0.05$ was considered to be statistically significant.

Results

I. Subjects

No significant differences between the boys and girls were observed for any of the maxillofacial morphology or nasal cavity function items at the initial examination, including Rohrer's index (Table 4).

II. Maxillofacial morphology

Tables 5 to 7 summarize the results of Kruskal-Wallis tests among the 3 groups of the items being analyzed from the lateral cephalograms. SNB, McNamara to Pogonion, facial angle, and U1-FH were significantly smaller in skeletal class II compared with skeletal class I, indicating mandibular retrusion. ANB and FMA were significantly larger in skeletal class II, indicating posterior rotation of

the mandible and labial inclination of the maxillary anterior teeth (Table 5).

Facial angle was significantly larger in skeletal class III compared with skeletal class I, indicating anterior positioning of the chin. SNA, ANB, and McNamara to A were significantly smaller in skeletal class III, showing poor maxillary growth. U1-FH, L1 to mandibular plane angle, and overjet were significantly smaller in skeletal class III, indicating that the skeletal class III cases were mainly related to maxillary retrusion (Table 6).

SNA, ANB, McNamara to A, L1 to mandibular plane angle, and overjet were significantly smaller in skeletal class III compared with skeletal class II, indicating maxillary retrusion. SNB, McNamara to Pogonion, and facial angle

were significantly larger in skeletal class III, a forward positioning of the chin and the mandible (Table 7).

Maxillary basal arch widths, mandibular basal arch widths and lengths were not significantly different between skeletal class I and II, skeletal class I and III, or skeletal class II and III. However, while maxillary basal arch lengths were not significantly different between skeletal class I and II, it was significantly smaller in skeletal class III compared with skeletal I and II (Table 8).

III. Maxillofacial morphology and olfaction

Significant differences in detection and recognition thresholds were not observed between skeletal class I and II. However, the detection and recognition thresholds of skeletal class III were significantly higher than those of

skeletal class I and II, indicating reduced olfaction (Figure 3).

IV. Correlations between maxillofacial morphology and olfaction

Significant differences were observed between SNA and detection threshold ($r = -0.498$) and between McNamara to A and recognition threshold ($r = -0.529$). Significant differences in detection or recognition thresholds were not observed between skeletal class I and II. However, both the detection and recognition thresholds were significantly higher in skeletal class III compared with skeletal class I and II (Figure 4).

VI. Maxillofacial morphology and nasal cavity ventilation

No significant differences were observed between any of the maxillofacial morphology and nasal cavity ventilation measurements (Table 9).

Discussion

Recently, the relationship between the growth and development of maxillofacial morphology and nasal cavity functions in children has been recognized as a problem. Iwasaki[13] and Galeotti et al.[14] investigated correlations between pediatric obstructive sleep apnea syndrome (OSAS) and maxillofacial morphology, and reported a higher incidence of pediatric OSAS among patients with poor maxillary growth. Moreover, measurements of nasal

cavity ventilation among children with malocclusion in the growth stage indicated that children with poor maxillary growth exhibit reduced nasal cavity functions. Sorokowska et al.[15] studied olfaction in 1,400 German subjects, and reported that olfaction had matured by approximately 10 years of age, and changed very little until the sixth decade of life. Scammon growth curves indicate that 90% of neural growth and development is completed by 6 years of age and 100% by 20 years of age. The subjects in the present study ranged in age from 6 to 12 years. At this age, improving reduced olfaction early by normalizing olfactory threshold values could help in increase enhancing quality of life.

· About our methods

According to a report by Miwa et al.,[16] the implementation rates of the standard olfactory test used in this study at pediatric medical institutions, hospitals, and clinics are 41%, 14%, and 7%, respectively, revealing that less than one-half of pediatric institutions perform this test. Disadvantages of T&T olfactometer® are that it requires specialized equipment, and takes time and effort. According to a report by Kubo et al.,[17] comparison of T&T olfactometer®, which is covered by health insurance in Japan, and the venous olfactory test indicated that there was no significant correlation between the olfactory result and clinical outcome.

In a study by Fujii et al.,[18] the results of T&T olfactometer® correlated significantly with the results of

a stick smell test. For this reason, we selected T&T olfactometer® to measure olfaction because it is simple to perform and is covered by health insurance.

The anterior method used to measure nasal cavity ventilation is easy to perform, does not cause significant patient discomfort, and can be performed quickly. One disadvantage is that it cannot be used in patients with unilateral nasal cavity obstruction.

The International Committee on Rhinomanometry Standards has defined the standard resistance value as PΔ150Pa. However, many Japanese individuals with normal nasal cavities cannot achieve 150 Pa with during resting respiration; therefore, the Japanese Rhinomanometry Committee recommends adopting 100 Pa. Subjects in the present study were children, and, according to Koh et

al.,[19] and Kobayashi et al.,[20] children have higher nasal cavity resistance than adults, which declines as they mature. Kobayashi et al.[20,21] reported the mean nasal resistance of Japanese children to be 0.43±0.50 Pa/cm^3/s.

In the present study, resistance was 0.50±0.30 Pa/cm^3/s, 0.45±0.10 Pa/cm^3/s, and 0.50±0.25 Pa/cm^3/s in skeletal classes I, II and III, respectively, which is consistent with the results reported by Kobayashi et al.[20,21] Moreover, nasal cavity resistance did not differ significantly among the 3 groups. Therefore, we show maxillofacial morphology is not associated with differences in the amount of nasal cavity air flow.

· About the subjects

To determine whether our cases represented typical malocclusion for skeletal class I, II, or III Japanese children, we compared measurements of mean height, weight, body mass index, and Rohrer's index values with a 2016 survey of school dental health statistics,[22] and no significant differences were found in them.

· Maxillofacial morphology and olfaction

The results of multiple comparisons of maxillofacial morphology between skeletal class I and II, skeletal class I and III, and skeletal class II and III, indicated that there were correlations in variables related to nasomaxillary complex such as in SNA and McNamara to A. Individuals in skeletal class III tend to have a small nasomaxillary

complex and exhibited the greatest reduction in olfaction, which indicates that the size of the nasomaxillary complex can affect olfaction. In addition, the basal arch in the maxillary molar area was significantly longer in skeletal class III compared with the other groups. Moreover, patients with shorter basal arches had higher olfactory thresholds. Therefore, children with malocclusion of skeletal mandibular protrusion with poor maxillary growth may experience reduced olfaction.

Hummel et al.[4] reported that left-right differences in olfactory bulb volumes were associated with differences in olfactory functions in humans. They reported that the larger the olfactory bulb volume, the better the olfactory function and the greater the sensitivity (i.e., lower olfactory threshold). These data suggest that olfactory bulb

volume reflects left-right tissue asymmetry, which may have some effect on left-right olfactory asymmetry. Furthermore, Altundag et al.[23] studied left-right differences and olfactory functions associated with nasal septum deviation. They found that the threshold, differentiation and identification of the type of the smell were less sensitive (lower) on the narrow side. Significant positive correlations were observed between olfactory bulb volume, olfactory threshold, differentiation, and identification of the type of smell, which indicates that olfactory functions are reduced on the narrower side of a deviated septum.

Although we did not examine olfactory bulb volume in the present study, we suggest that when the mandible portion of the nasomaxillary complex is smaller, the volume of the

olfactory bulb also tends to be smaller and, as a result, increases the olfaction threshold. Felippe et al.[24] reported that when nasal cavity volume increased by rapid maxillary expansion, upper airway resistance decreased. Cappellette et al.[25] found that rapid maxillary expansion expanded all structures of the nasomaxillary complex (nasal cavity, oropharynx, left-right maxillary sinuses). Ottaviano et al.[26] suggested that nasal cavity resistance after rapid maxillary expansion may improve olfaction thresholds for n-butanol.

Therefore, these results suggest that children with skeletal mandibular protrusion and small maxilla may lead to better olfactory thresholds if malocclusion is improved (i.e., treated).

Conclusion

We performed maxillofacial measurements and olfactory tests to clinically investigate relationships between nasal cavity functions and maxillofacial morphology among individuals with malocclusion during the growth and development stage. The results demonstrated that children with malocclusion and skeletal mandibular protrusion associated with poor maxillary growth tend to exhibit reduced olfaction. This suggests that there is a correlation between maxillary growth and development, and olfaction.

As orthodontists, we should provide treatment for children during growth and development to correct maxillofacial morphology, which may also improve olfactory functions. In the future, we plan to investigate how malocclusion therapy impacts olfactory function.

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Figure legends

Fig. 1. Reference points and lines on the cephalograms. Definition of dental and skeletal reference points and lines are those reported by Thompson (5).

Fig. 2. Measurements of the dental cast.

Fig. 3. Correlation between maxillofacial morphology and olfaction.

Fig. 4. Relationship between maxillofacial morphology and olfaction.

Tables

Table 1. Definitions of angles (degrees) and linear measurements (mm), used in cephalometric measurements

Table 2. Words expressing qualities of standard odors*

*From Toyota et al., 1978; courtesy of Igaku-Shoin, Ltd., Tokyo.

Table 3. Categorization of olfactory sensitivity into six classes on the basis of averages of recognition thresholds in olfactograms*

*From Toyota et al., 1978; courtesy of Igaku-Shoin, Ltd., Tokyo

Table 4. Characteristics among skeletal Class I, II, and III groups

Table 5. Comparison of individuals in skeletal Class I and II in cephalometric measurements

Table 6. Comparison of individuals in skeletal Class I and III in cephalometric measurements

Table 7. Comparison of individuals in skeletal Class II and III in cephalometric measurements

Table 8. Relationship between maxillofacial morphology and dental cast

Table 9. Relationship between maxillofacial morphology and rhinomanometry

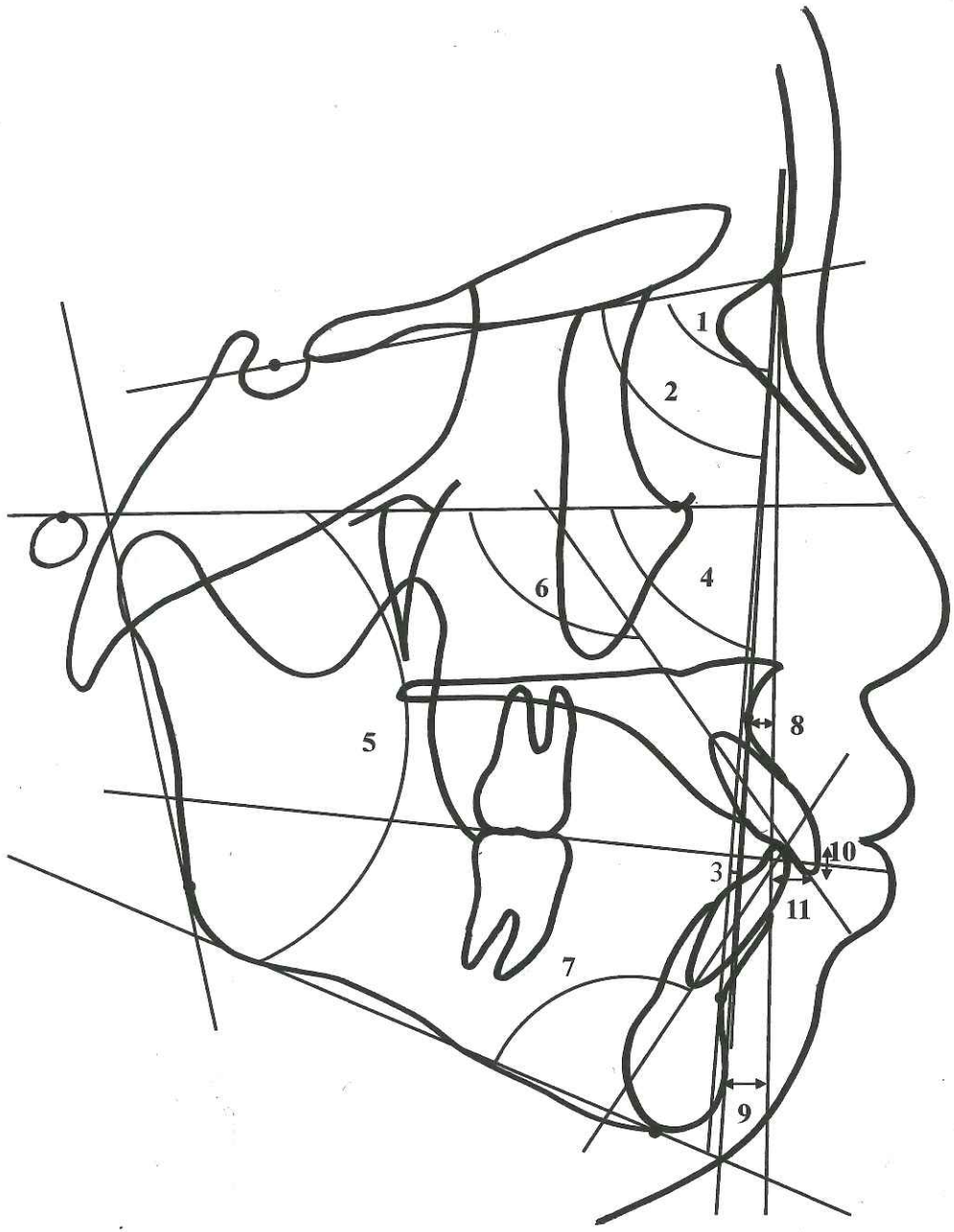


Fig.1 Reference points and lines on the cephalograms. Definition of dental and skeletal reference points and lines are those given by Thompson (1949) .

Table 1. Definitions of angular (degrees),and linear (mm), used in cephalometric measurements

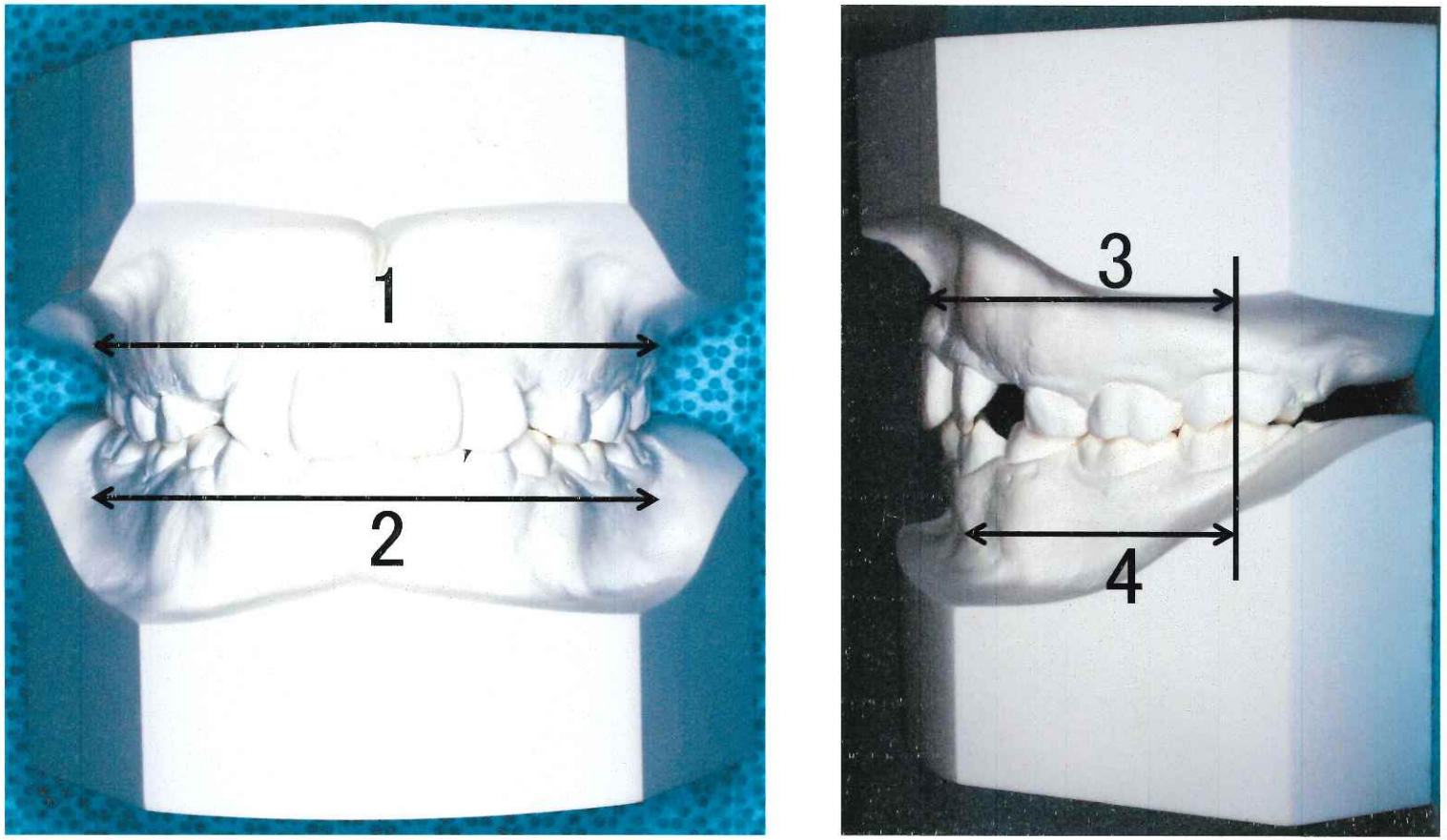
Variable
1, SNA(°)
2, SNB(°)
3, ANB(°)
4, Facial angle(°)
5, FMA(°)
6, U1-FH(°)
7, L1 to mandibular plane angle(°)
8, McNamara to A(mm)
9, McNamara to Pogonion (mm)
10, Overbite(mm)
11, Overjet(mm)

Table 2. Example of odors word presenting verbal information used for odor identification.
(from Toyota et al., 1978; courtesy of Igaku-Shoin, Ltd., Tokyo)

Standard odor	Words expressing qualities ofatandard odors
A	Odor of rose, light sweet odor
B	Burnt odor, caramel odor
C	Putrid odor, odor of long-worn socks, aweaty odor, odor of fermented soybeans
D	Canned peach odor, heavy sweet odor
E	Fecal odor, odors of vegetable garvage, oral odor oraversive, Bad odor

Table 3. Categorization of olfactory sensitivity into six classes on the basis of averages of recognition thresholds in olfactograms.(from Toyota et al., 1978; courtesy of Igaku-Shoin, Ltd., Tokyo)

Olfactory loss : Average recognition threshold	Degree of olfactory disorder	Complaint of patient
～-1.0	Hyperosmic	
-1.0～1.0	Normal or normosmic	All odors detected normally No olfactory problem in daily life
1.1～2.5	Normal or mildly hyposmic	All odors detected midly
2.6～4.0	Moderately hyposmic	Only strong odors detected
4.1～5.5	Severely hyposmic	Odors scarcely detected
5.5～	Anosmic	No odors detected



1. Maxillary alveolar basal arch width at first molars
2. Mandible alveolar basal arch width at first molars
3. Maxillary alveolar basal arch length at first molars
4. Mandible alveolar basal arch length at first molars

Fig.2 Measurements of dental cast

Table. 4 Characteristics between the groups (Skeletal Class I, Skeletal Class II and Skeletal Class III)

	Skeletal Class I (n=22) Mean(SD)	Skeletal Class II (n=24) Mean(SD)	Skeletal Class III (n=22) Mean(SD)	Kruskal - Wallis
Height(cm)	134.39(±10.81)	134.82(±9.12)	134.40(±9.06)	NS
Body weight(kg)	32.30(±10.77)	30.76(±6.99)	30.10(±5.34)	NS
BMI	17.43(±3.43)	16.79(±2.58)	16.60(±1.52)	NS
Rohrer Index	129.65(±21.03)	109.00 (±12.00)	123.80(±12.80)	NS

NS: not significant

Table 5. Comparison of Skeletal Class I and Skeletal Class II in cephalometric measurements

	Skeletal Classn I (n=22)	Skeletal Class II (n=24)	Kruskal - Wallis
	Mean(SD)	Mean(SD)	
SNA(°)	80.54(±2.83)	80.24(±3.83)	NS
SNB(°)	77.42(±2.76)	73.98(±3.66)	* *
ANB(°)	3.12(±0.54)	6.24(±1.92)	* *
McNamara to A(mm)	-1.04(±3.38)	-0.01(±3.13)	NS
McNamara to Pogonion(mm)	-8.38(±6.49)	-11.47(±6.84)	*
Facial A.(°)	85.89(±3.06)	83.80(±3.74)	*
FMA(°)	28.86(±4.33)	31.63(±5.72)	*
U1-FH(°)	118.43(±7.48)	112.24(±5.91)	*
L1-Mp(°)	88.85(±15.81)	94.84(±5.54)	NS
Overbite(mm)	2.33(±2.24)	3.10(±1.64)	NS
Overjet(mm)	3.88(±2.88)	4.27(±2.12)	NS

* P < .05, * * P < .01, NS: not significant

Table 6. Comparison of Skeletal Class I and Skeletal Class III in cephalometric measurements

	Skeletal Class I (n=22)	Skeletal Class III (n=22)	Kruskal - Wallis
	Mean(SD)	Mean(SD)	
SNA(°)	80.54(±2.83)	79.53(±3.01)	*
SNB(°)	77.42(±2.76)	80.10(±3.35)	NS
ANB(°)	3.12(±0.54)	-0.10(±1.18)	* *
McNamara to A(mm)	-1.04(±3.38)	-2.40(±2.40)	*
McNamara to Pogonion(mm)	-8.38(±6.49)	-4.30(±4.41)	NS
Facial A.(°)	85.89(±3.06)	87.40(±2.99)	*
FMA(°)	28.86(±4.33)	28.9(±5.07)	NS
U1-FH(°)	118.43(±7.48)	112.50(±6.14)	*
L1-Mand.P.(°)	88.85(±15.81)	85.30(±5.49)	*
Overbite(mm)	2.33(±2.24)	2.50(±2.10)	NS
Overjet(mm)	3.88(±2.88)	-0.6(±2.76)	*

* P < .05, * * P < .01, NS: not significant

Table 7. Comparison of Skeletal Class II and Skeletal Class III in cephalometric measurements

	Skeletal Class II (n=24)	Skeletal Class III (n=22)	Kruskal - Wallis
	Mean(SD)	Mean(SD)	
SNA(°)	80.24(±3.83)	79.53(±3.01)	*
SNB(°)	73.98(±3.66)	80.10(±3.35)	* *
ANB(°)	6.24(±1.92)	-0.10(±1.18)	* *
McNamara to A(mm)	-0.01(±3.13)	-2.40(±2.40)	* *
McNamara to Pogonion(mm)	-11.47(±6.84)	-4.30(±4.41)	* *
Facial A.(°)	83.80(±3.74)	87.40(±2.99)	*
FMA(°)	31.63(±5.72)	28.9(±5.07)	NS
U1-FH(°)	112.24(±5.91)	112.50(±6.14)	NS
L1-Mand.P.(°)	94.84(±5.54)	85.30(±5.49)	* *
Overbite(mm)	3.10(±1.64)	2.50(±2.10)	NS
Overjet(mm)	4.27(±2.12)	-0.6(±2.76)	* *

* P < .05, * * P < .01, NS: not significant

Table 8. Relation between maxillofacial morphology and dental cast

	Skeletal Class I (n=22)Mean(SD)	Skeletal Class II (n=24)Mean(SD)	Skeletal Class III (n=22)Mean(SD)	I vs II	I vs III	II vs III
Maxillary alveolar basal arch width (mm)	59.55	59.90	58.90	NS	NS	NS
	(±2.61)	(±4.67)	(±4.67)			
Maxillary alveolar basal arch length (mm)	28.17	27.91	26.00	NS	*	*
	(±3.03)	(±3.41)	(±2.78)			
Mandible alveolar basal arch width (mm)	59.09	58.02	58.70	NS	NS	NS
	(±2.69)	(±4.98)	(±1.97)			
Mandible alveolar basal arch length (mm)	28.98	27.96	27.20	NS	NS	NS
	(±1.70)	(±2.50)	(±2.96)			

* P < .05, NS: not significant

Table 9.Relation between maxillofacial morphology and Rhinomanometry

	Skeletal Class I (n=22) Mean(SD)	Skeletal Class II (n=24) Mean(SD)	Skeletal Class III (n=22) Mean(SD)	Kruskal –Wallis	Kruskal - Wallis	Kruskal -Wallis
				I vs II	I vs III	II vs III
Bilateral nasal cavity 100In ($Pa/cm^3/sec$)	0.50(±0.30)	0.45(±0.10)	0.50(±0.25)	NS	NS	NS

NS: not significant

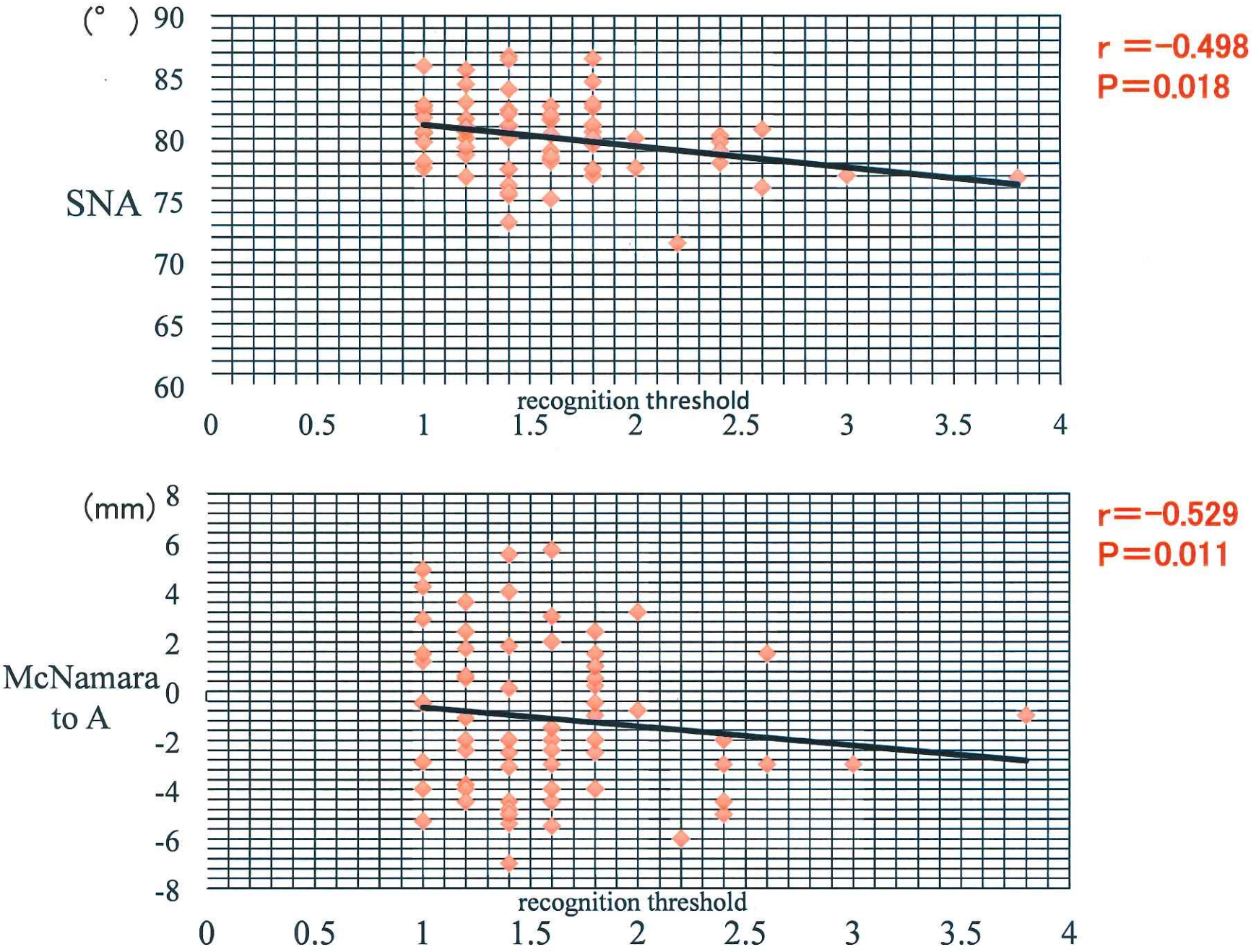


Fig.3 Correlation between maxillofacial morphology and olfaction.

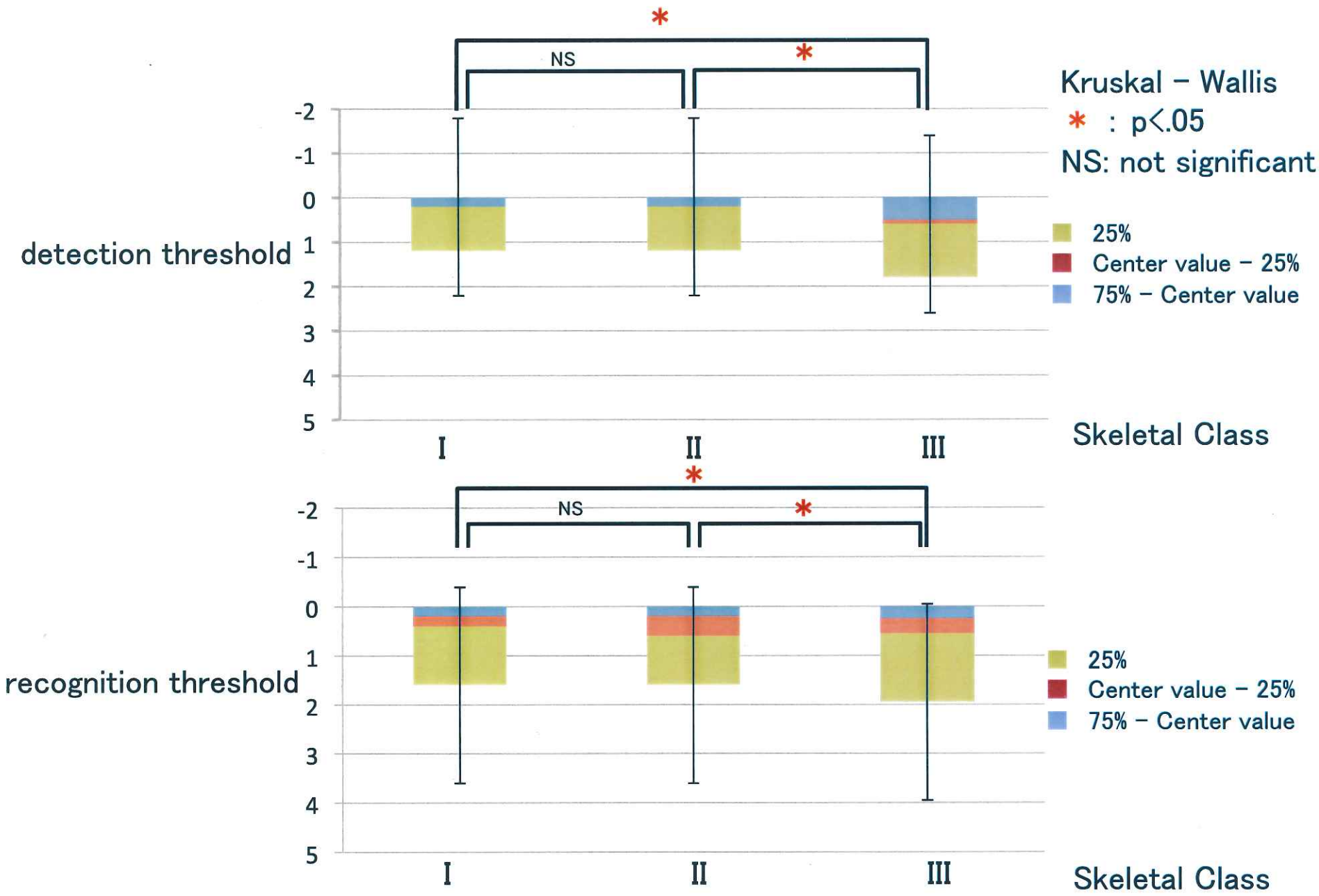


Fig.4 Relation between maxillofacial morphology and olfaction