Evaluation of Maxillary and Mandibular Growth Pattern Based on Cervical Vertebral Maturation in Japanese

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Evaluation of maxillary and mandibular growth pattern based on cervical vertebral maturation in Japanese

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Abstract

Appropriate evaluation of maxillofacial growth and development is important for effective orthodontic treatment. The evaluation of growth is not based on chronological age, but on the physiological age that is evaluated according to individual development. The cervical vertebral bone age is one approach to evaluate physiological age. In the present study, we evaluated the growth pattern of maxilla and mandible in Japanese patients using the age of the cervical vertebrae as an index. Lateral cephalometric radiographs taken before the start of the orthodontic treatment were traced to evaluate the age of the cervical vertebrae and mandible. Altogether, 400 patients were allocated to groups based on the cervical vertebral maturation stages (CVMS), namely, CVMS I to V, with 80 patients in each group. In this study, stratified random sampling was used to obtain the required samples. We measured ANS-PNS as an index of maxillary length, whereas Ar-Go as an index of mandibular height and Go-Pog as an index of mandibular length on the cephalograms. It was found that ANS-PNS increased significantly between CVMS II and CVMS III, while both Ar-Go and Go-Pog increased significantly between CVMS III and CVMS IV in men. On the other hand, such significant increases in consecutive stages were not found in women. Based on these observations, it was suggested that CVMS is effective in evaluating the growth pattern of the maxilla and mandible.

Introduction

In the field of orthodontics, growth and development of the maxillofacial skeleton has been extensively studied. Growth evaluation is inevitable for diagnosis in orthodontic treatment, treatment alternatives, and determination of treatment starting time. Orthodontists have attempted the use of bone age and tooth age as physiological age growth evaluation. There have been numerous reports on the use of carpal bones for evaluation of bone age as they contain many bone nuclei, can be radiographed easily, and require a smaller exposure dose[1–3]. An alternative to this method is the cervical spine maturation method (CVM), which evaluates the shape of the cervical spine obtained from lateral cephalometric radiographs. There are various methods to evaluate tooth age: Hellman's tooth age, which is based on the eruption status; the Demirjian method[4], which evaluates the degree of calcification of seven permanent teeth from panoramic radiographs; and the Cameriere method[5], which evaluates the degree of root formation.

The cervical spine consists of seven vertebrae, and it supports the skull. Ossification of the cervical spine continues from the embryonic stage into adulthood[6]. The CVM was proposed by Lamparski et al[7]. In 1972, and in 2002, Baccetti et al. created an improved version of the CVM to facilitate staging[8].
Previous research has reported that CVM correlates with carpal bone age assessment and is also suitable for mandibular growth assessment. The size of the mandibular bone and timing of growth are important to achieve good intermaxillary relationships in orthodontic treatment[9,10]. However, to the best of our knowledge, only a few previous reports have investigated the growth of maxilla and mandible[11–14] in the Japanese population with an unclarified growth pattern. Furthermore, no previous research surveyed the size of both the maxilla and mandible measured simultaneously.

Therefore, the purpose of this study was to (1) determine the standard maxillary and mandibular bone size and (2) evaluate the growth pattern of maxillary and mandibular height and length and (3) use the age of the cervical spine as an aid in orthodontic diagnosis.

Results

The κ coefficient for the degree of intra-evaluator agreement was 0.89, and the κ coefficient for the degree of inter-evaluator agreement was 0.91, both showing almost perfect agreement. The measurement error for Ar-Go was 0.63 mm, as calculated by Dahlberg's formula, and the measurement error for Go-Pog was 0.67 mm, which was a sufficiently small error.

The average values of ANS-PNS in men were 49.31 ± 2.74 mm in CVMS I, 50.76 ± 2.99 mm in CVMS II, 53.11 ± 2.56 mm in CVMS III, 54.95 ± 3.19 mm in CVMS IV, and 55.88 ± 3.42 mm in CVMS V. There was a significant increase in the ANS-PNS value in CVMS I compared to CVMS III, IV and V, in CVMS II compared to CVMS III, IV and V, and in CVMS III compared to CVMS V (Fig. 2). The average values of ANS-PNS in women were 49.10 ± 2.61 mm in CVMS I, 49.46 ± 2.45 mm in CVMS II, 50.66 ± 2.24 mm in CVMS III, 51.56 ± 2.34 mm in CVMS IV, and 51.53 ± 2.13 mm in CVMS V. There was no significant increase in the ANS-PNS value across all groups; however, there was a significant increase between CVMS I and CVMS V (Fig. 3).

The average values of Ar-Go in men were 46.80±3.76 mm in CVMS I, 45.55±4.88 mm in CVMS II, 46.93±5.16 mm in CVMS III, 53.15±6.44 mm in CVMS IV, and 54.94±5.87 mm in CVMS V. There was a significant increase in the Ar-Go value in CVMS I compared to CVMS IV and V, in CVMS II compared to CVMS IV and V, and in CVMS III compared to CVMS IV and V (Fig. 4). The average values of Ar-Go in women were 45.36±5.24 mm in CVMS I, 45.11±4.56 mm in CVMS II, 46.75±5.45 mm in CVMS III, 50.57±6.25 mm in CVMS IV, and 50.76±6.66 mm in CVMS V. There was no significant increase in the Ar-Go value across all groups; however, there was a significant increase between CVMS I and CVMS V (Fig. 5).

The average values of Go-Pog in men were 79.57±3.97 mm in CVMS I, 80.24±5.22 mm in CVMS II, 80.73±5.56 mm in CVMS III, 85.80±6.55 mm in CVMS IV, and 87.97±6.35 mm in CVMS V. There was a significant increase in the Go-Pog value in CVMS I compared to CVMS IV and V, in CVMS II as compared to that in CVMS IV and V, and in CVMS III compared to CVMS IV and V (Fig. 6). The average values of Go-Pog in women were 80.23±4.96 mm in CVMS I, 80.68±4.20 mm in CVMS II, 82.04±4.48 mm in CVMS III, 84.14±5.63 mm in CVMS IV, and 86.66±7.23 mm in CVMS V. There was no significant increase in the Go-Pog value across all groups; however, there was a significant increase between CVMS I and CVMS V (Fig. 7).

Discussion

Identifying the growth spurt of maxilla and mandible is important for orthodontic treatment during the growth period. However, it is considered difficult to predict because of the various differences resulting from the growth spurt of height[10]. At present, carpal roentgens are regarded as the gold standard to assess bone maturation[9]. In fact, there are several reports on the correlation between the ages determined using carpal bones and the cervical spine[10,15–17], while the British Orthodontic Society stated that there are uncertainty using carpal radiography in predicting patient's adolescent growth spurt[17]. Lateral cephalometric radiographs are indispensable for clinical orthodontic treatment planning and are often taken at the time of the first visit. It is considered clinically valuable to identify growth predictors by means of lateral cephalometric radiographs.

In relation to the growth pattern, the height of the mandible was significantly larger in men than in women. On the other hand, there was no significant difference in the mandibular length between men and women. As has been previously reported in the literature, the height and length of the mandible are significantly larger in men[18–20]. Accordingly, we measured the actual mandibular length to determine the differences between men and women.

A headgear known as extra-oral anchorage device can suppress or redirect the overgrowth of the maxilla by using the head or neck as a fixative anchorage.[21] In the past, it has been reported that the use of a removable functional appliance in the treatment of maxillary anterior protrusion during the growth period results in slight suppression of maxillary growth[22]. Maxillary length ANS-PNS showed a significant increase from CVMS 2 to CVMS 3 in men, revealing the appearance of maxillary growth spurts. Therefore, it is necessary to predict growth tendency via the growth patterns during diagnosis and thereafter.

In this study, the mandibular height (Ar-Go) and length (Go-Pog) increased between the period of CVMS III and CVMS IV. In patients with mandibular prognathism, orthodontists try to achieve normal overbite and overjet with skeletal discrepancy in dental compensation. However, when large skeletal discrepancy is present, a normal overbite and overjet cannot be constructed by dental compensation alone. To correct the anteroposterior jaw position and realign the intermaxillary relation with consideration for the mandible (toward the tendency of elimination of dental compensation) after tooth movement, orthognathic surgery can be used to achieve an adequate maxillo-mandibular relation by splitting the maxillo-mandibular jaw bone in combination with orthodontic treatment[23,24]. To be specific, the decompensation direction in maxillary and mandibular anterior teeth revealed opposite from dental compensation in non-surgery mandibular prognathism cases. Orthodontists establish a treatment plan in accordance with the degree of skeletal discrepancy. Nevertheless, if the mandibular spurt is misread, the construction of a normal overbite and overjet cannot be achieved by orthodontic treatment alone. Mistakes in treatment decisions can lead to complications, such as prolonged treatment and root resorption. Moreover, in cases of maxillary prognathism with mandibular retraction, a good intermaxillary relationship can be obtained by inducing the anterior growth of the mandible. Therefore, it was suggested that it is desirable to initiate treatment during CVMS III in men when inducement of mandibular growth is needed. In addition, mandibular prognathism during the growth period may be managed by a combination of orthodontic and surgical treatment when mandibular growth is remarkable[17,25]. Previous reports have indicated that controlling mandibular growth with functional orthopedic appliance devices is effective in growing patients with skeletal discrepancy[26]. In cases while the observation of mandibular growth is considered needed, it is pondered difficult to determine the appropriate timing to initiate treatment based on findings of CVMS III. Both CVMS and chronological ages should be considered to anticipate future growth potential. It is advisable to initiate treatment during CVMS IV, which presents the period of mandibular growth plateaus. The confirmation of CVMS on lateral cephalometric radiographs thus facilitates orthodontic treatment planning.

Compared to men, women were not acknowledged as having a relatively obvious growth spurt of the maxilla and mandible. Indeed, there has been a study reporting that Japanese women revealed a clarified presentation of growth spurt.[27] For orthodontic treatment during growth period in women, a treatment plan that incorporates the difference between women and men regarding growth pattern should be carefully considered.

A previous research has demonstrated that CVM can be easily evaluated on lateral cephalometric radiographs and is accounted to be adequate for prediction of the adolescent growth spurt for mandibular growth[26]. Nevertheless, there are reports of this method lacking reproducibility among evaluators[28]. Numerous experienced orthodontists do not measure the shape of the cervical vertebrae before initiating the treatment, which may be explained by a possible lack of skills for tracing and measuring the cervical bone. Whereas in our research, the weighted kappa coefficient showed an intra-evaluator reproducibility of 0.89, and an inter-evaluator reproducibility of 0.91, both of which were considered almost perfect. Additionally, according to evidence, CVM evaluation can be inaccurate due to a rotation error[29]. As a matter of fact that CT had been performed without stabilisation of the head with the ear rod in the related study. Accordingly, lateral cephalometric radiographs were used for determination of the CVM in our study. In lateral cephalometric radiographs, rotation of the horizontal and vertical planes is regulated by ear rods, and rotation errors are indicated to be significantly minimised. Additionally, the x-ray tube is as long as the patient's midsagittal plane, and the film are always stabilised and stabilised at a certain distance. Thus, the lateral cephalometric radiographs are standardised, and it is widely known that their reproducibility is relatively high with fewer errors. Numerous clinicians, including orthodontists, are aware regarding the change in the shape and size of the cervical spine changes with growth and that lateral cephalometric radiographs reflect the growth and age of the cervical spine. Appropriate treatment of patients based on prediction of the mandibular growth preferably without additional radiational exposure is recognised as a priority. We believe that it is particularly important for orthodontists to study the growth of the cervical spine for improved treatment outcomes.

The limitations of present study include its cross-sectional design and inability to follow the continuing growth of individuals. In spite of the fact that the capability of cross-sectional study surveying large subject number of individual and its insensitivity to induvidual difference, while we highlighted the compatibility of this method to our study with the calculation of standard value. Ideally, a longitudinal survey would be preferable. Nonetheless, previous research has exhibited of its reproducibility and statistical analysis[16]. Hence, in modern times individual as us, for ethical reasons, it is considered rarely possible to take lateral cephalometric radiographs for untreated patients on an annual basis.

Methods

This cross-sectional study was approved by the Ethics Committee of Tokyo Medical and Dental University (TMDU) Dental Hospital (D2021-026). All research procedures were conducted in accordance with ethical guidelines of the Ministry of Health, Labor and Welfare for medical research in humans. The patients or their guardians provided written informed consent before inclusion in the study. The subjects were patients of Japanese descent, aged between six to 20 years, who visited the outpatient department of the Department of Orthodontics, Tokyo Medical and Dental University Dental Hospital. Random coefficients were assigned to a list of 4000 patients in total, and samples to be measured were randomly selected. Further, random sampling was repeated until the sample size of each CVMS group was achieved[30]. Eighty patients were randomly selected and allocated to each group based on the maturation stage, with a total of 400 patients included in the study. The study groups were based on the cervical vertebral maturation stages (CVMS) I-V. CVMS I: second (odontoid process, C2), third (C3) and fourth (C4) The lower ends of the cervical vertebrae are all flat. C3 and C4 are trapezoidal in shape. In CVMS

II, a dent is present at the bottom of C2 and C3. C3 and C4 are trapezoidal or horizontally long rectangles. In CVMS III, indentations are present on the lower edges of C2, C3, and C4. C3 and C4 are rectangular is shape. In CVMS IV, C3 or C4 is square-shaped. Also, the other cervical vertebrae are still long rectangular in the mesio-distal direction. In CVMS V, C3 or C4 is has a vertically long rectangle shape. The other cervical vertebrae are also square[6]. Patients with syndromes that could influence the maxillofacial morphology were excluded. Descriptive characteristics of the patients are summarised in Table I.

The a priori sample size estimation, performed at a 5% level of significance (α=0.05), with a power of 80%, revealed that a minimum of 40 subjects were necessary per age group. Lateral cephalometric radiographs taken before initiating the orthodontic treatment were traced, and measurement points were plotted (Fig. 1).

All lateral cephalometric radiographs were taken in accordance with international standards. ANS-PNS was measured as an evaluation of the horizontal diameter of the maxilla , Ar-Go was measured as an evaluation of the vertical diameter of the mandible, and Go-Pog was measured as an evaluation of the horizontal diameter of the mandible[9,10,31]. The WinCeph ver.9 (Rise Corp., Tokyo, Japan) software was used to perform the measurements.

One investigator performed the measurement three times, and the average was used as the measured value; however, the evaluation was verified by another investigator. In addition, the population was predicted by restoration extraction using the bootstrapping with 1000 iterations. The measurement error of each measured value was calculated using Dahlberg's formula[25] For statistical analysis, the Kruskal-Wallis test was performed for comparison between the groups, and then multiple tests were performed using the Steel-Dwass test. Additionally, to verify the reliability of the CVMS determination, the weighted Kappa coefficient was calculated based on the degree of intra-evaluator and inter-evaluator agreement. The degree of intra-evaluator agreement was based on two CVM staging decisions made by one evaluator at an interval of 3 weeks. The degree of inter-evaluator agreement was based on the CVMS determined by each of the two evaluators. SPSS version 25 (Statistical Package of Social Sciences, Chicago, IL, USA) was used as the test software.

References

1. Pichai, S. *et al.* A Comparison of Hand Wrist Bone Analysis with Two Different Cervical Vertebral Analysis. *J. Int. Oral Health* 6.
2. Santiago, R. C. *et al.* Cervical vertebral maturation as a biologic indicator of skeletal maturity: A systematic review. *Angle Orthod.* **82**, 1123–1131 (2012).
3. Szemraj, A., Wojtaszek-Słomińska, A. & Racka-Pilszak, B. Is the cervical vertebral maturation (CVM) method effective enough to replace the hand-wrist maturation (HWM) method in determining skeletal maturation?—A systematic review. *Eur. J. Radiol.* **102**, 125–128 (2018).
4. Goya, H. A., Satake, T., Maeda, T., Tanaka, S. & Akimoto, Y. Dental age in Japanese children using a modified Demirjian method. 7.
5. Cameriere, R., Ferrante, L. & Cingolani, M. Age estimation in children by measurement of open apices in teeth. *Int. J. Legal Med.* **120**, 49–52 (2006).
6. Miller, C. A., Hwang, S. J., Cotter, M. M. & Vorperian, H. K. Cervical vertebral body growth and emergence of sexual dimorphism: a developmental study using computed tomography. *J. Anat.* **234**, 764–777 (2019).
7. Lamparski DG. Skeletal age assessment utilizing cervical vertebrae. *Am J Orthod* **67**, 458–459 (1975).
8. Baccetti, T., Franchi, L. & Jr, J. A. M. An Improved Version of the Cervical Vertebral Maturation (CVM) Method for the Assessment of Mandibular Growth. *Angle Orthod.* **72**, 8 (2002).
9. Freudenthaler, J., Čelar, A., Ritt, C. & Mitteröcker, P. Geometric morphometrics of different malocclusions in lateral skull radiographs. *J. Orofac. Orthop.* **78**, 11–20 (2017).
10. Omran, A., Wertheim, D., Smith, K., Liu, C. Y. J. & Naini, F. B. Mandibular shape prediction using cephalometric analysis: applications in craniofacial analysis, forensic anthropology and archaeological reconstruction. *Maxillofac. Plast. Reconstr. Surg.* **42**, (2020).
11. Franchi, L., Nieri, M., McNamara, J. A. & Giuntini, V. Predicting mandibular growth based on CVM stage and gender and with chronological age as a curvilinear variable. *Orthod. Craniofac. Res.* **24**, 414–420 (2021).
12. Baccetti, T., Reyes, B. C. & McNamara, J. A. Craniofacial changes in Class III malocclusion as related to skeletal and dental maturation. *Am. J. Orthod. Dentofacial Orthop.* **132**, 171.e1-171.e12 (2007).
13. Chen, L.-L., Xu, T.-M., Jiang, J.-H., Zhang, X.-Z. & Lin, J.-X. Longitudinal changes in mandibular arch posterior space in adolescents with normal occlusion. *Am. J. Orthod. Dentofacial Orthop.* **137**, 187–193 (2010).
14. Miyajima, K., McNamara, J. A., Sana, M. & Murata, S. An estimation of craniofacial growth in the untreated Class III female with anterior crossbite. *Am. J. Orthod. Dentofacial Orthop.* **112**, 425–434

(1997).
15. Nanda, S. K. Patterns of vertical growth in the face. *Am. J. Orthod. Dentofacial Orthop.* **93**, 103–116 (1988).
16. Coben, S. E. The integration of facial skeletal variants: A serial cephalometric roentgenographic analysis of craniofacial form and growth. *Am. J. Orthod.* **41**, 407–434 (1955).
17. David, O.-T., Tuce, R.-A., Munteanu, O., Neagu, A. & Panainte, I. Evaluation of the influence of patient positioning on the reliability of lateral cephalometry. *Radiol. Med. (Torino)* **122**, 520–529 (2017).
18. Jacob, H. B. & Buschang, P. H. Mandibular growth comparisons of Class I and Class II division 1 skeletofacial patterns. *Angle Orthod.* **84**, 755–761 (2014).
19. Coquerelle, M. *et al.* Sexual dimorphism of the human mandible and its association with dental development. *Am. J. Phys. Anthropol.* **145**, 192–202 (2011).
20. Rosas, A. & Bastir, M. Thin-plate spline analysis of allometry and sexual dimorphism in the human craniofacial complex. *Am. J. Phys. Anthropol.* **117**, 236–245 (2002).
21. Papageorgiou, S. N. *et al.* Effectiveness of early orthopaedic treatment with headgear: a systematic review and meta-analysis. *Eur. J. Orthod.* **39**, 176–187 (2017).
22. Fudalej, P. & Bollen, A.-M. Effectiveness of the cervical vertebral maturation method to predict postpeak circumpubertal growth of craniofacial structures. *Am. J. Orthod. Dentofac. Orthop. Off. Publ. Am. Assoc. Orthod. Its Const. Soc. Am. Board Orthod.* **137**, 59–65 (2010).
23. Alexander, A. E. Z., McNamara, J. A., Franchi, L. & Baccetti, T. Semilongitudinal cephalometric study of craniofacial growth in untreated Class III malocclusion. *Am. J. Orthod. Dentofac. Orthop. Off. Publ. Am. Assoc. Orthod. Its Const. Soc. Am. Board Orthod.* **135**, 700.e1–14; discussion 700-701 (2009).
24. Georgalis, K. & Woods, M. G. A study of Class III treatment: orthodontic camouflage vs orthognathic surgery. *Aust. Orthod. J.* **31**, 138–148 (2015).
25. Galvão, M. C. de S., Sato, J. R. & Coelho, E. C. Dahlberg formula: a novel approach for its evaluation. *Dent. Press J. Orthod.* **17**, 115–124 (2012).
26. Baccetti, T., Franchi, L. & McNamara, J. A. The Cervical Vertebral Maturation (CVM) Method for the Assessment of Optimal Treatment Timing in Dentofacial Orthopedics. *Semin. Orthod.* **11**, 119–129 (2005).
27. Sato, K., Mitani, H., Kurita, S. A study on growth timing of several components of cranio-facial-cervical region and standing height - from 6 years of age to adulthood-. *Tohoku Univ Dent J.* **6**,71-79 (1987) (in Japanese).
28. Gabriel, D. B. *et al.* Cervical vertebrae maturation method: Poor reproducibility. *Am. J. Orthod. Dentofacial Orthop.* **136**, 478.e1-478.e7 (2009).
29. Mehta, S. *et al.* Effect of positional errors on the accuracy of cervical vertebrae maturation assessment using CBCT and lateral cephalograms. *J. World Fed. Orthod.* **9**, 146–154 (2020).
30. Pandis, N., Polychronopoulou, A. & Eliades, T. Randomization in clinical trials in orthodontics: its significance in research design and methods to achieve it. *Eur. J. Orthod.* **33**, 684–690 (2011).
31. Ochoa, B. K. & Nanda, R. S. Comparison of maxillary and mandibular growth. *Am. J. Orthod. Dentofacial Orthop.* **125**, 148–159 (2004).

Author Contributions List

I.T designed and summarized this study. A.M performed data extraction, analysed the results and wrote the main manuscript text. E.K advised on statistical analysis. T.O reviewed and revised the manuscript, and approved the final manuscript as submitted. All authors read and approved the final version of the manuscript.

Additional Information

The authors declare no competing interests.

Figure legends

Figure 1. Cephalometric landmarks used to construct the two linear measurements and angular measurements analyzed in this study. Linear parameters: ANS-PNS; Distance between ANS and PNS, Ar-Go; Distance between Articulare and Gonion, Go-Pog; Distance between Gonion and Pogonion. Angular parameters: FMA; Mandibular plane to Frankfort-Horizontal plane, SNA; Sella-Nasion to Point A, SNB; Sella-Nasion to Point B

Figure 2. The average values of ANS-PNS in men were 49.31±2.74 mm in CVMS I, 50.76±2.99 mm in CVMS II, 53.11±2.56 mm in CVMS III, 54.95±3.19 mm in CVMS IV, and 55.88±3.42 mm in CVMS V. There was a significant increase in the ANS-PNS value in CVMS I as compared to that in CVMS III, IV and V, in CVMS II as compared to that in CVMS III, IV and V, and in CVMS III as compared to that in CVMS V (*$p<0.05$).

Figure 3. The average values of ANS-PNS in women were 49.10±2.61 mm in CVMS I, 49.46±2.45 mm in CVMS II, 50.66±2.24 mm in CVMS III, 51.56±2.34 mm in CVMS IV, and 51.53±2.13 mm in CVMS V. There was a significant increase in the ANS-PNS value in CVMS I as compared to that in CVMS IV and V, in CVMS II as compared to that in CVMS IV and V (*$p<0.05$).

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Table 1. Descriptive statistics of patient variables. S.D.: Standard deviation. FMA; Mandibular plane to Frankfort-Horizontal plane, SNA; Sella-Nasion to Point A, SNB; Sella-Nasion to Point B

	CVMS 1				CVMS 2				CVMS 3				CVMS 4				CVMS 5			
	M n=40		F n=40		M n=40		F n=40		M n=40		F n=40		M n=40		F n=40		M n=40		F n=40	
	mean (median)	S.D.	mean (median)	S.D.	mean (median)	S.D.	mean (median)	S.D.	mean (median)	S.D.	mean (median)	S.D.	mean (median)	S.D.	mean (median)	S.D.	mean (median)	S.D.	mean (median)	S.D.
age[Y]	10.08	3.14	9.85	3.01	11.06	3.13	10.70	3.04	12.16	1.82	11.72	3.06	16.06	3.10	15.22	2.89	17.29	3.48	16.96	3.37
	9.33		9.25		9.33		9.17		12.13		10.75		16.46		15.71		18.50		18.54	
FMA[°]	29.79	4.84	29.47	5.52	26.45	5.06	29.01	5.54	28.03	5.20	27.00	4.56	26.85	4.94	29.11	4.55	30.22	6.92	31.01	7.09
	30.05		29.30		30.00		28.00		27.70		27.05		27.35		28.80		29.70		32.35	

SNA[°]	79.99 3.22	81.77 3.19	80.61 3.22	81.07 3.39	80.97 3.86	81.64 3.19	81.11 3.39	79.41 3.64	81.48 3.34	80.93 2.97
	80.25	82.25	80.15	82.25	81.66	82.15	81.05	79.35	81.30	81.05
SNB[°]	76.73 3.44	76.95 3.90	76.78 3.58	77.37 4.16	76.59 4.31	78.59 3.65	79.67 4.60	76.31 4.61	80.19 4.74	78.49 4.87
	76.85	76.65	76.90	77.10	76.10	78.22	79.05	75.30	80.05	78.55

Figures

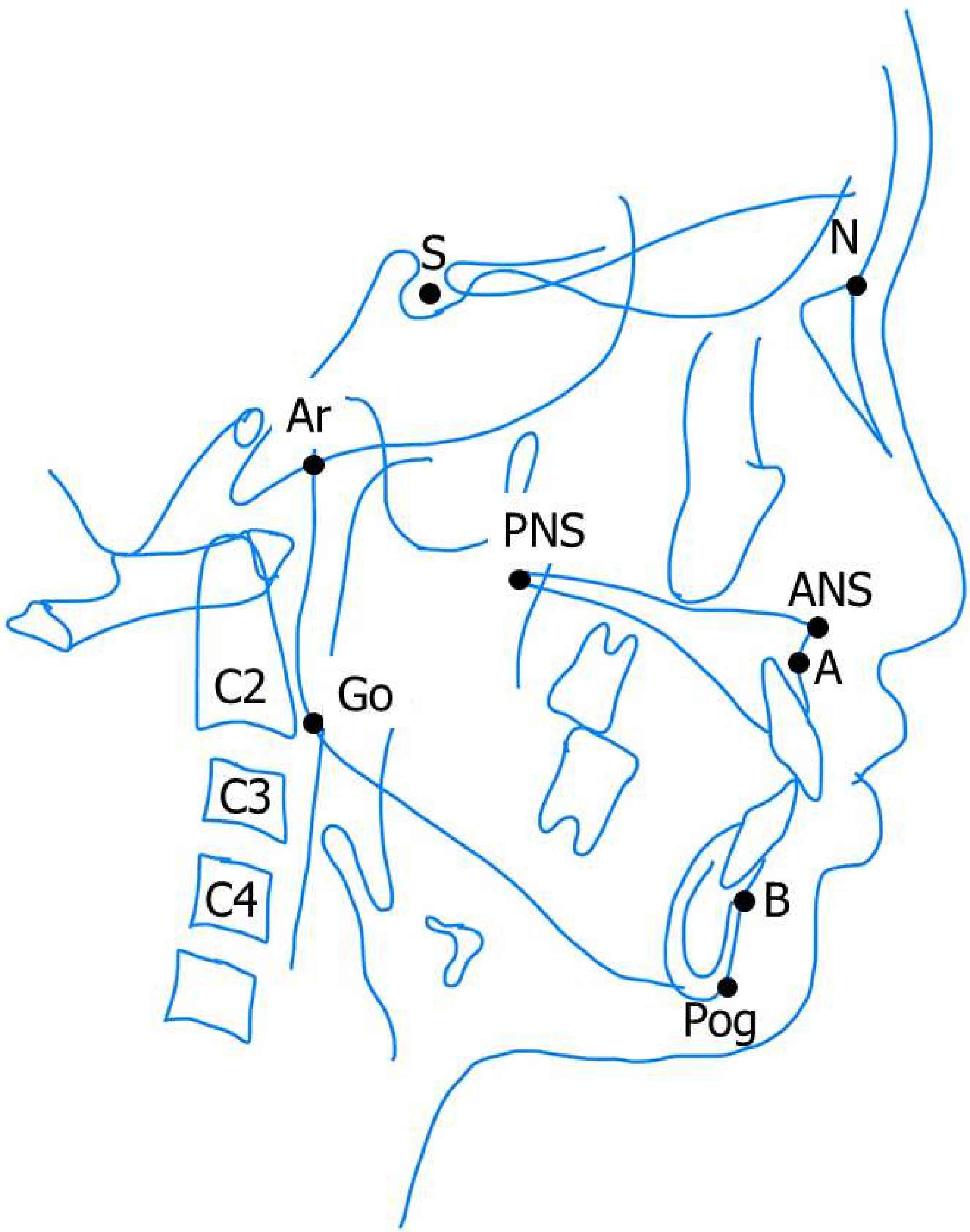

Figure 1

Cephalometric landmarks used to construct the two linear measurements and angular measurements analyzed in this study. Linear parameters: ANS-PNS; Distance between ANS and PNS, Ar-Go; Distance between Articulare and Gonion, Go-Pog; Distance between Gonion and Pogonion. Angular parameters:

FMA; Mandibular plane to Frankfort-Horizontal plane, SNA; Sella-Nasion to Point A, SNB; Sella-Nasion to Point Cephalometric landmarks used to construct the two linear measurements and angular measurements analyzed in this study. Linear parameters: ANS-PNS; Distance between ANS and PNS, Ar-Go; Distance between Articulare and Gonion, Go-Pog; Distance between Gonion and Pogonion. Angular parameters: FMA; Mandibular plane to Frankfort-Horizontal plane, SNA; Sella-Nasion to Point A, SNB; Sella-Nasion to Point

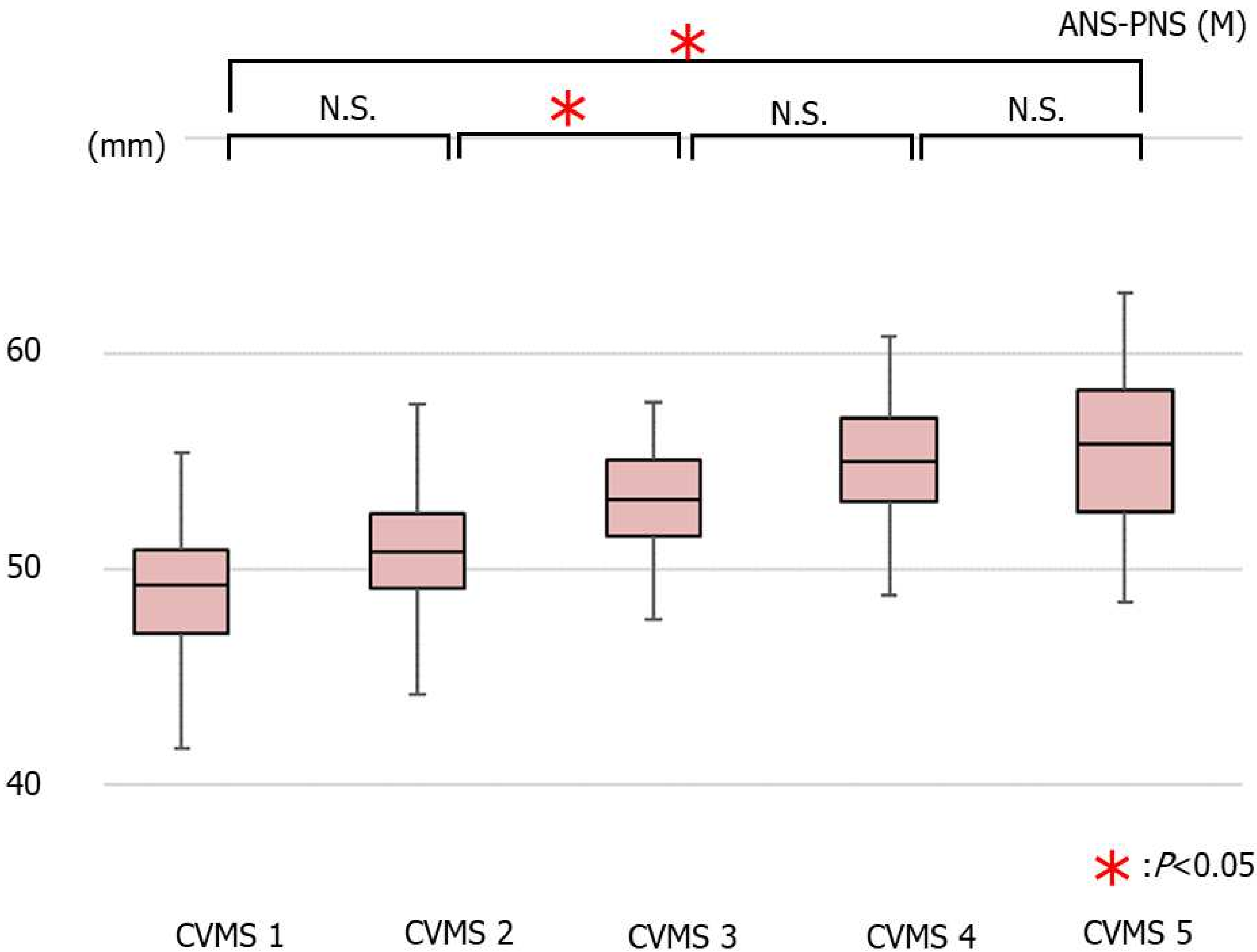

Figure 2

The average values of ANS-PNS in men were 49.31±2.74 mm in CVMS I, 50.76±2.99 mm in CVMS II, 53.11±2.56 mm in CVMS III, 54.95±3.19 mm in CVMS IV, and 55.88±3.42 mm in CVMS V. There was a significant increase in the ANS-PNS value in CVMS I as compared to that in CVMS III, IV and V, in CVMS II as compared to that in CVMS III, IV and V, and in CVMS III as compared to that in CVMS V (*p<0.05).

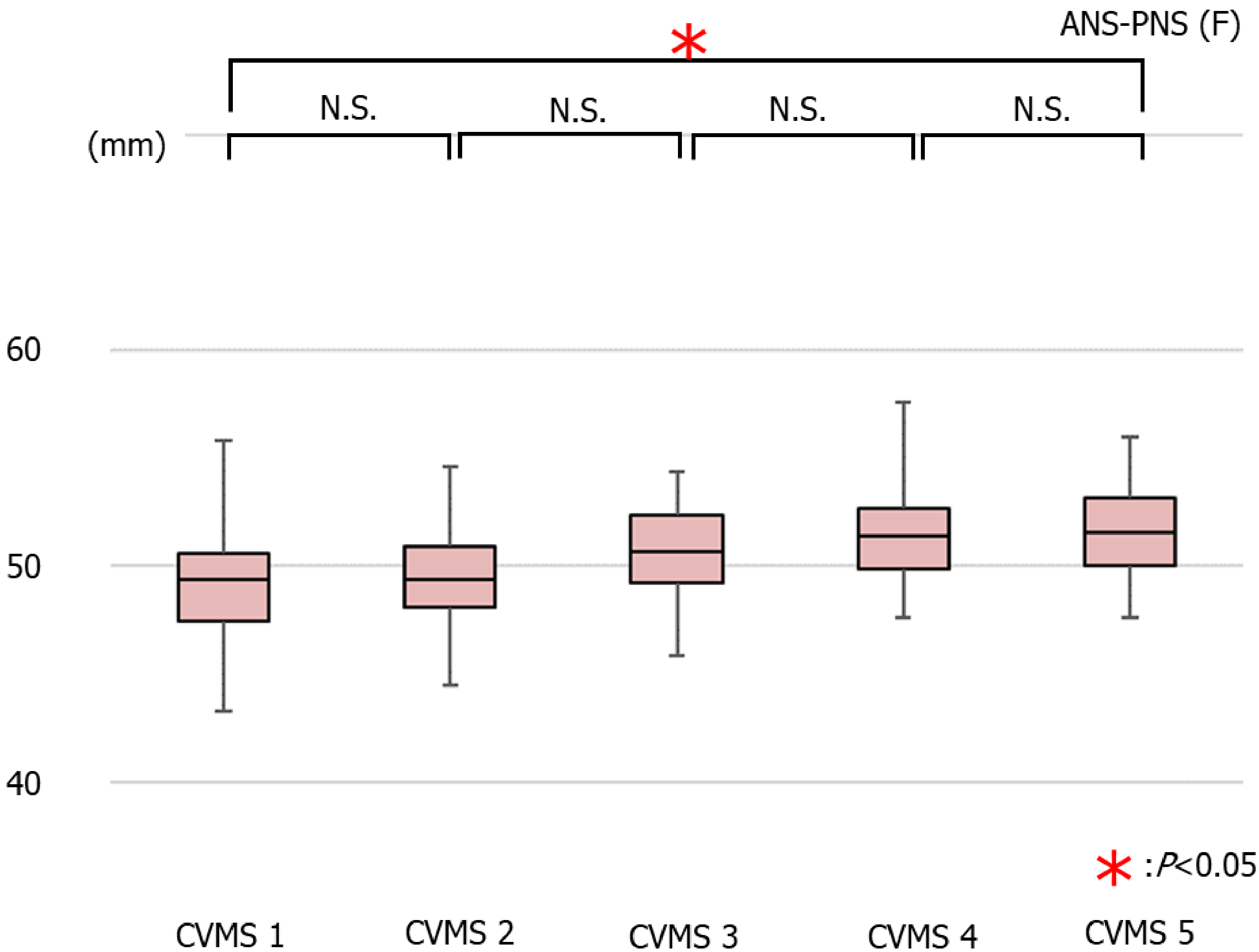

Figure 3

The average values of ANS-PNS in women were 49.10±2.61 mm in CVMS I, 49.46±2.45 mm in CVMS II, 50.66±2.24 mm in CVMS III, 51.56±2.34 mm in CVMS IV, and 51.53±2.13 mm in CVMS V. There was a significant increase in the ANS-PNS value in CVMS I as compared to that in CVMS IV and V, in CVMS II as compared to that in CVMS IV and V (*p<0.05).

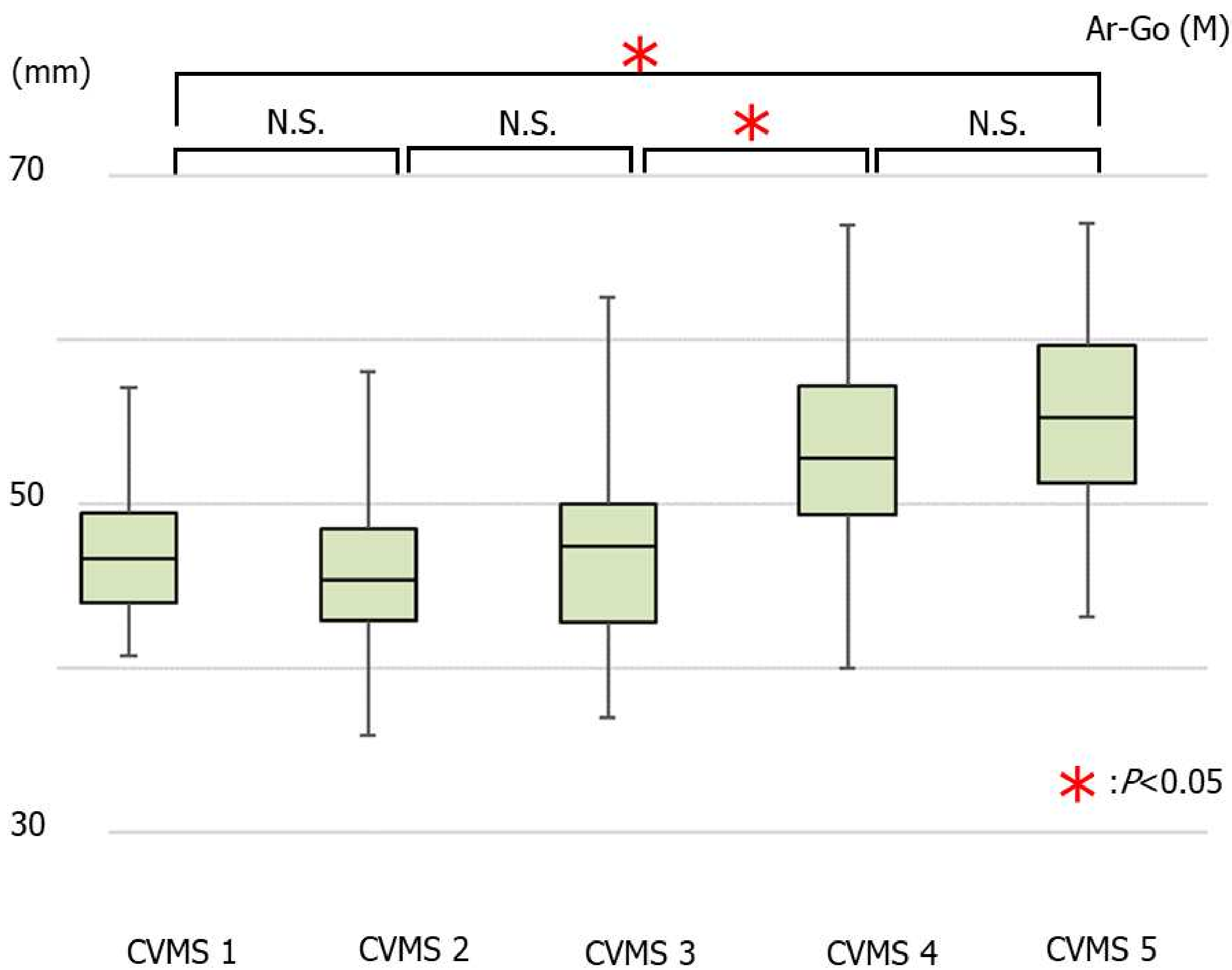

Figure 4

The average values of Ar-Go in men were 46.80±3.76 mm in CVMS I, 45.55±4.88 mm in CVMS II, 46.93±5.16 mm in CVMS III, 53.15±6.44 mm in CVMS IV, and 54.94±5.87 mm in CVMS V. There was a significant increase in the Ar-Go value in CVMS I as compared to that in CVMS IV and V, in CVMS II as compared to that in CVMS IV and V, and in CVMS III as compared to that in CVMS IV and V (*p<0.05).

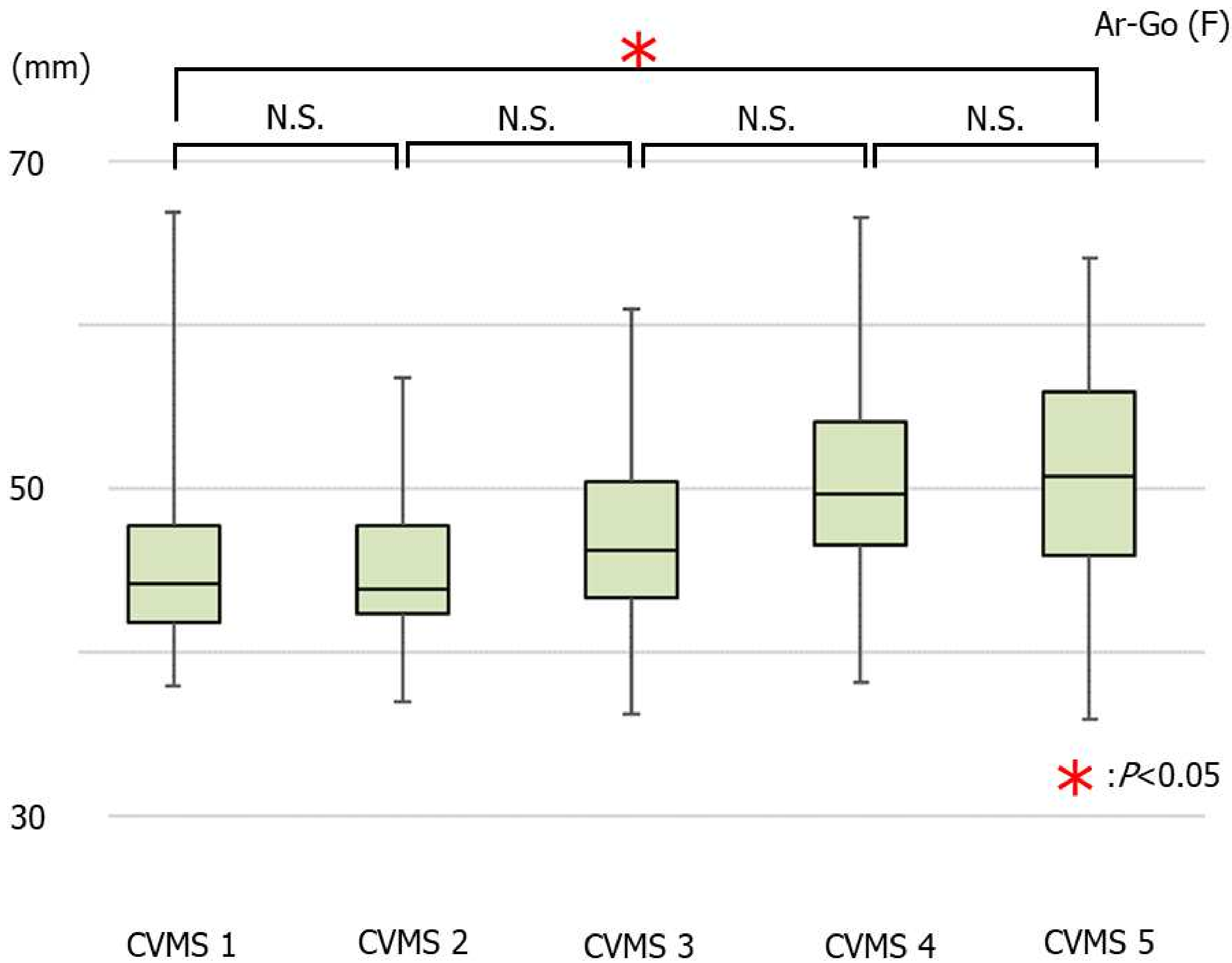

Figure 5

The average values of Ar-Go in women were 45.36±5.24 mm in CVMS I, 45.11±4.56 mm in CVMS II, 46.75±5.45 mm in CVMS III, 50.57±6.25 mm in CVMS IV, and 50.76±6.66 mm in CVMS V. There was a significant increase in the Ar-Go value in CVMS I as compared to that in CVMS IV and V, in CVMS II as compared to that in CVMS IV and V (*p<0.05).

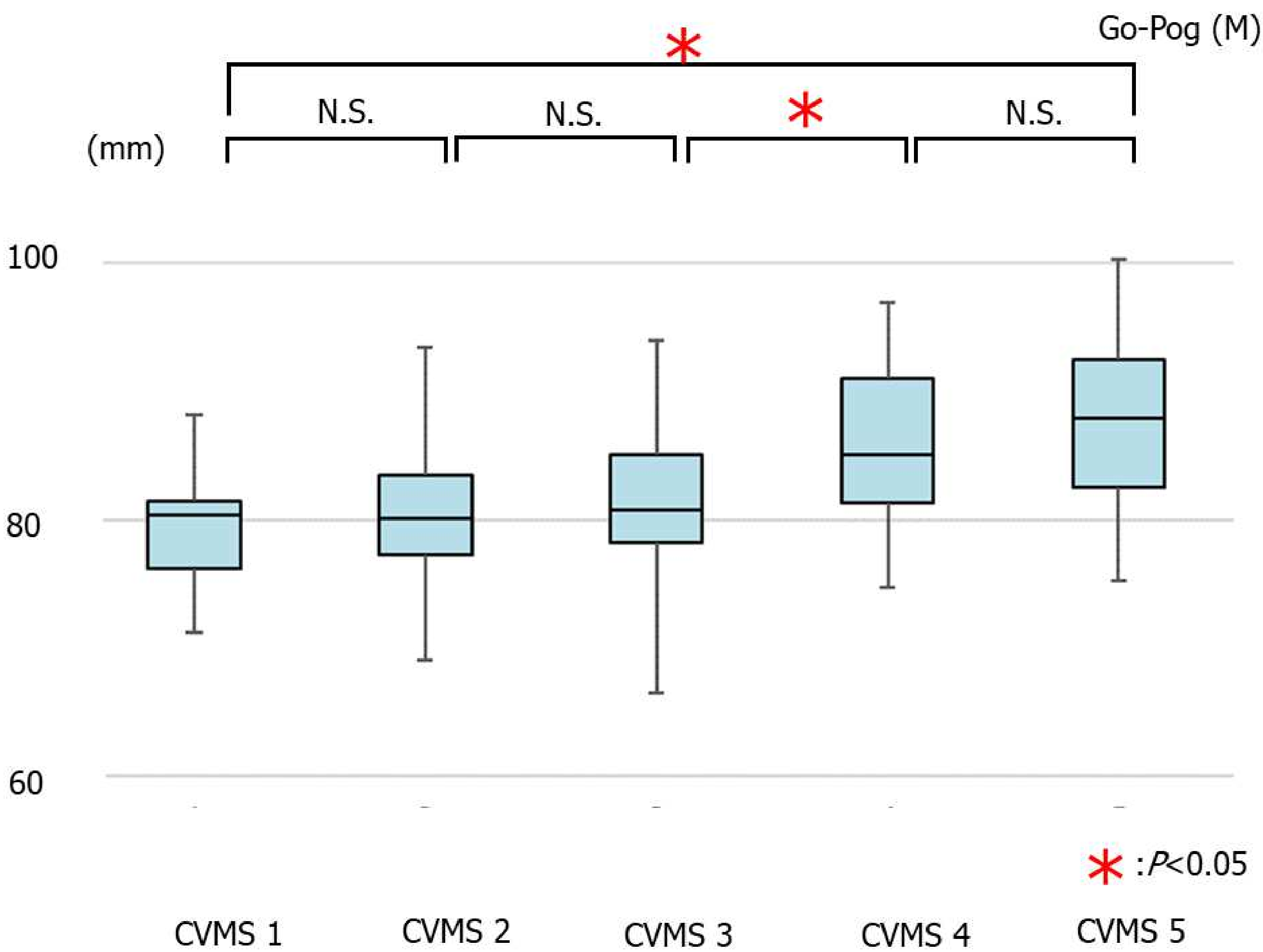

Figure 6

The average values of Go-Pog in men were 79.57±3.97 mm in CVMS I, 80.24±5.22 mm in CVMS II, 80.73±5.56 mm in CVMS III, 85.80±6.55 mm in CVMS IV, and 87.97±6.35 mm in CVMS V. There was a significant increase in the Go-Pog value in CVMS I as compared to that in CVMS IV and V, in CVMS II as compared to that in CVMS IV and V, and in CVMS III as compared to that in CVMS IV and V (*p<0.05).

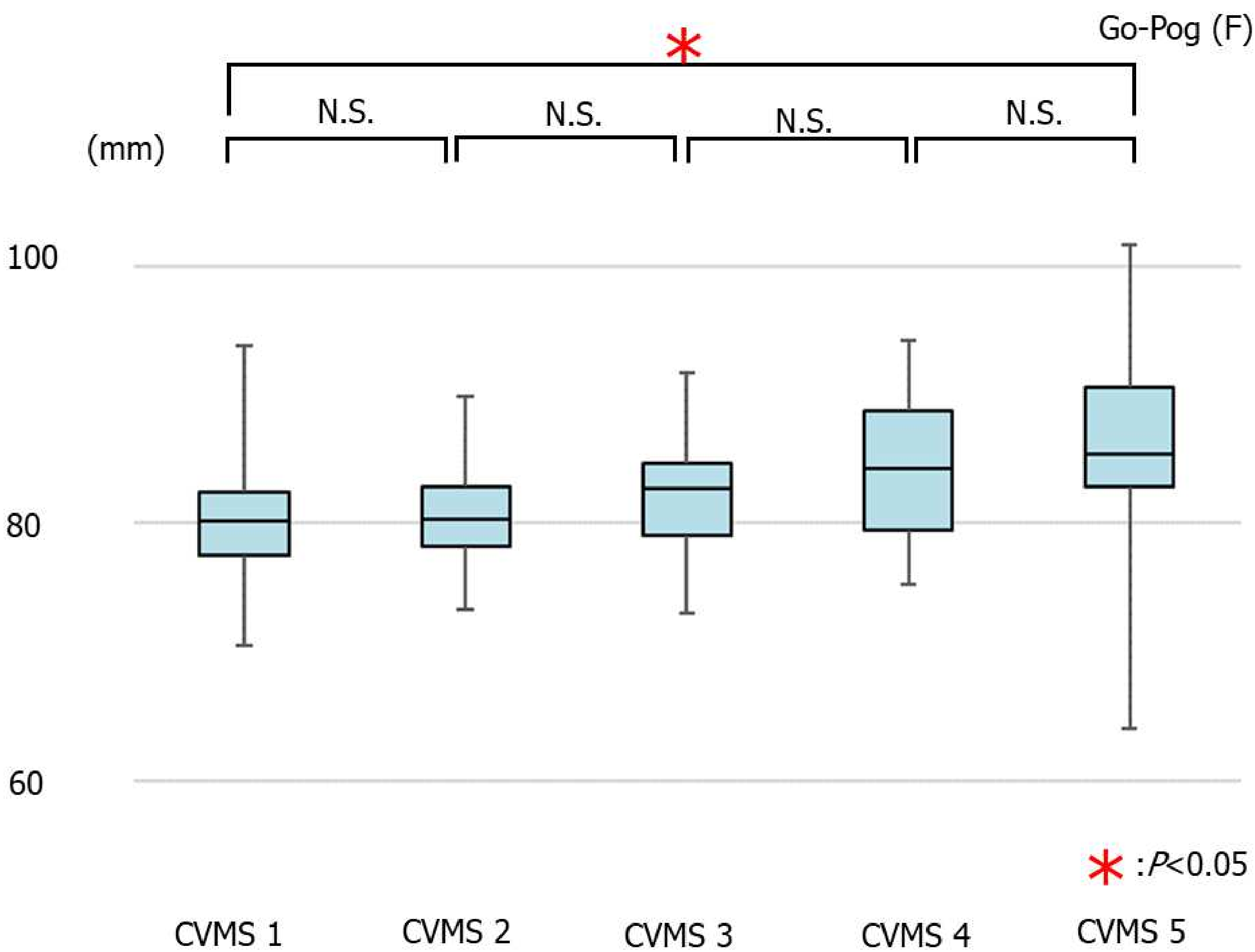

Figure 7

The average values of Go-Pog in women were 80.23±4.96 mm in CVMS I, 80.68±4.20 mm in CVMS II, 82.04±4.48 mm in CVMS III, 84.14±5.63 mm in CVMS IV, and 86.66±7.23 mm in CVMS V. There was a significant increase in the Go-Pog value in CVMS I as compared to that in CVMS IV and V, in CVMS II as compared to that in CVMS V, and in CVMS III as compared to that in CVMS V(*p<0.05).