


Temporomandibular Disorder Signs, Occlusal Support, and Craniofacial Structure Changes Among the Elderly Vietnamese

Minh Son Nguyen^{1,2}  · Mare Saag¹ · Ülle Voog-Oras¹ · Toai Nguyen³ · Triin Jagomägi¹

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Abstract

Objective The aim of study was to determine the association between signs of temporomandibular disorders (TMD), occlusal support, and alterations in the craniofacial structure of elderly Vietnamese by using cephalometric analysis.

Methods The cross-sectional study consisted of 244 participants aged 65–74 years. Participants were examined for signs of TMD, including limited mouth opening, temporomandibular joint (TMJ) crepitus, TMJ tenderness, and muscle tenderness. Dentition was divided into four occlusal support zones based on occluding pairs of posterior teeth by using Eichner's classification: Class A = 4 support zones; Class B = 1–3 support zones or only contact in anterior teeth; Class C = 0 support zones. Fifteen angular and seven linear parameters were used for sagittal craniofacial skeleton analysis.

Results 10.3% of participants had limited mouth opening, 49.6% TMJ crepitus, 16.3% TMJ tenderness, and 24.2% muscle tenderness; 45.5% had Class A occlusal support, 38.5% Class B, and 16.0% Class C. Those with Class C had significantly smaller ramus inclination, articular angle, and angles formed by the mandibular plane and shorter facial height compared to Class A and Class B ($P < .001$). TMD

signs were significantly associated with: angles formed by mandibular plane, gonial angle, cranial base angle, effective mandibular length, and anterior facial height ($P < .05$).

Conclusions The alteration of craniofacial structures was significantly associated with TMD signs among elderly Vietnamese. The higher number of lost occlusal support zones, the more significant the changes to craniofacial structures.

Keywords Cephalometry · Elderly · Occlusion · Temporomandibular disorders

Introduction

Temporomandibular disorders (TMD) are a major concern regarding the oral health of elderly people. Signs of TMD occur in 40% of elderly people worldwide and increase with age. Most signs co-occur with TMD are temporomandibular joint sounds at levels ranging from 28 to 38% [1, 2]. Masticatory muscle tenderness has been observed in 14% of elderly people and is considered to cause of impaired masticatory performance [3], and a limited mouth opening occurs more often among the elderly than any other age group [2].

Elderly people often have occlusal problems owing to a progressive loss of teeth, and they have to adapt new functional mastication, which can lead to a change in the movement trajectory of the temporomandibular joint (TMJ). Missing teeth can reduce the vertical dimension of occlusion, cause imbalanced occlusion, and influence neuromuscular adaptation, as well as increase the likelihood of TMD [4]. Hiltunen et al. [5] found an association between inadequate occlusal support and TMD.

✉ Minh Son Nguyen
minhson1883@gmail.com

¹ Institute of Dentistry, University of Tartu, 6 Raekoja Plats, 51003 Tartu, Estonia

² Department of Prosthodontics, Danang University of Medical Technology and Pharmacy, 99 Hung Vuong, Danang 550000, Vietnam

³ Hue University of Medicine and Pharmacy, 06 Ngo Quyen, Hue 530000, Vietnam

Facial harmony affects esthetics, functionality, and social communication. Cephalometry has a significant role in the analysis of alterations to craniofacial structures. A decreased vertical dimension of occlusion can result in alteration of the anterior facial height [6]. Many studies have used cephalometry to examine changes to the mandibular structures of edentulous people [7–10]. Progressive tooth loss results in a larger gonial angle and a smaller ramus of the mandible [8, 9].

Other investigations have used magnetic resonance imaging (MRI) and cone beam computerized tomography (CBCT) to observe changes to the structures of the temporomandibular joint; however, the high exposure to radioactivity and cost of these methods are disadvantages of these methods compared to cephalography. Cephalography has been recognized as a supporting tool for craniofacial morphology analysis of TMD patients [11–16]. Emshoff et al. [13] found accordance between cephalometric and MRI analysis of TMJ structural characteristics. In addition, cephalometric findings significantly associated with TMD; Matsuo et al. [15] showed that the ratio between the condyle and ramus heights was lower among subjects with TMJ crepitus. Chen et al. [12] demonstrated that a degenerative TMJ joint results in a decreased posterior facial height, while Ahn et al. [11] suggested that several cephalometric parameters could be used as an auxiliary diagnostic tool for identifying patients with TMJ internal derangement. Anterior open-bite and Class II malocclusion based on cephalometric measurements are considered risk factors for TMD [17].

Facial skeletal characteristics differ between ethnic groups, and the cephalometric characteristics of a Vietnamese sample had not been studied yet. In addition, the number of occlusal supports affects the stability and balance of occlusion, which is known as the key to preventing TMD, but this has not been investigated using cephalometric analysis, including among elderly people, who often have missing teeth. Last, significant associations between TMD signs and craniofacial structures have been insufficiently reported based on the cephalometric analysis.

Therefore, the aim of this study was to determine the association between signs of temporomandibular disorders, occlusal support and alteration in the craniofacial structure of elderly Vietnamese based on cephalometric measurements.

Materials and Methods

Study Sample Size

This cross-sectional study involved examining the oral health, temporomandibular disorder status, and occlusion

of elderly people aged 65–74 years living in Danang City, Vietnam. The sample size was calculated at a 90% confidence level; hypothesizing the prevalence of TMD in elderly Vietnamese is 50%; this gave an acceptable margin of error of 5%. The total sample equaled 300 participants. The selection criteria for participation were absence of physical and mental disabilities, and no history of TMJ trauma or orthodontic or facial surgery.

A multistage stratified random sampling method was used to select participants based on their demographic characteristics. One rural district and three urban districts were randomly taken from eight districts of Danang city for the current study. Lists of elderly citizens were obtained from the Community Unions for Older Adults, into which all those aged 65–74 years are incorporated. Finally, participants from each of selected urban district (50 subjects) and rural (150 subjects) were randomly sampled and stratified according to gender. The sample selection is shown in Fig. 1.

Written informed consent that explained detailed study procedures including clinical examination and cephalography was obtained from all participants. This study was approved by the Human Research Ethics Committee of Danang University of Medical Technology and Pharmacy (No. 523/CN-DHKTYDDN) and performed in accordance with the World Medical Association's Helsinki Declaration.

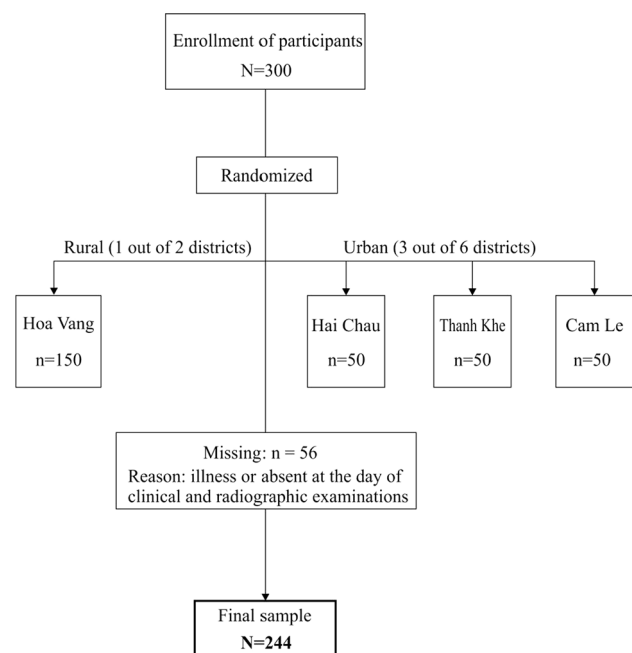


Fig. 1 Flowchart of the multistage stratified random sampling method used to select elderly participants aged 65–74 years living in Danang, Vietnam

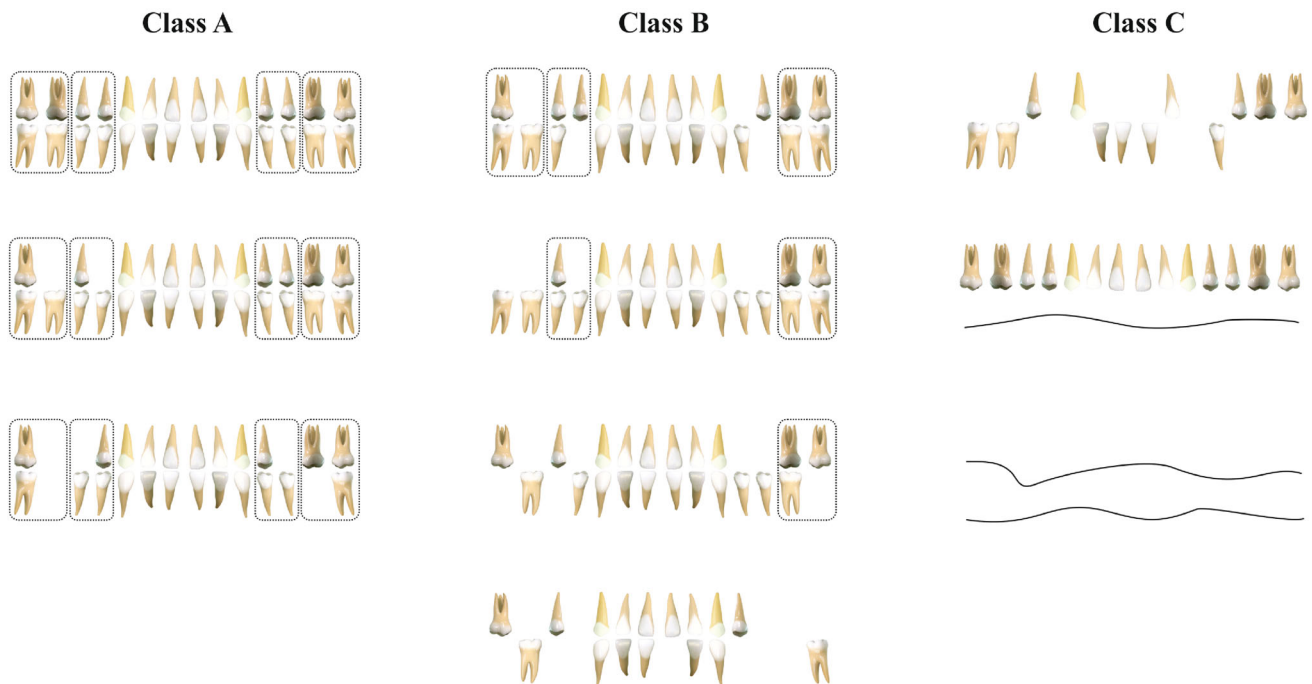


Fig. 2 Eichner's classification: Class A (4 occlusal support zones); Class B (1–3 occlusal support zones, or only contact in anterior teeth); Class C (no occlusal support zones)

Signs of TMD

Signs of TMD were based on clinical examination using the Diagnosis Criteria for Temporomandibular disorders (DC/TMD) Axis I [18]. TMD signs consisted of: limited mouth opening (maximum assisted mouth opening <40 mm); deviation of mouth-opening pattern; TMJ clicking and/or crepitus sounds during mandibular movement; TMJ tenderness; muscle tenderness.

The first author who was trained by professional expert for diagnosis of TMD conducted all clinical temporomandibular examinations. A pilot study of a group of 25 elderly people was performed to calibrate the examiner, and ten percent of the total sample were re-examined after 3 days to test the reliability of the examination. The calculated Kappa values were above 0.85, indicating a high degree of intra-examiner and inter-examination reliability.

Occlusal Support

An alginate impression was taken for fabrication of a diagnostic cast, and the participant's centric occlusion was recorded using a wax bite. After a dental cast has been scanned, occlusion was analyzed using Ortho Analyzer™ software (3Shape A/S, Copenhagen, Denmark).

Occlusal support was analyzed using Eichner's classification [19], which divides the posterior teeth into four zones based on the existence of occluding pairs of posterior teeth. Class A equates to contact at all four support zones;

Class B lacks at least one support zone, or the loss of all four supporting zones but intact anterior region; Class C has no contact of any coupled teeth. The number of occlusal support zones is shown in Fig. 2. In cases where a participant had fixed crowns or bridge prosthesis, these were also considered as remaining teeth; however, a removable prosthesis, a stump or broken tooth were registered as missing teeth.

Cephalometric Analysis

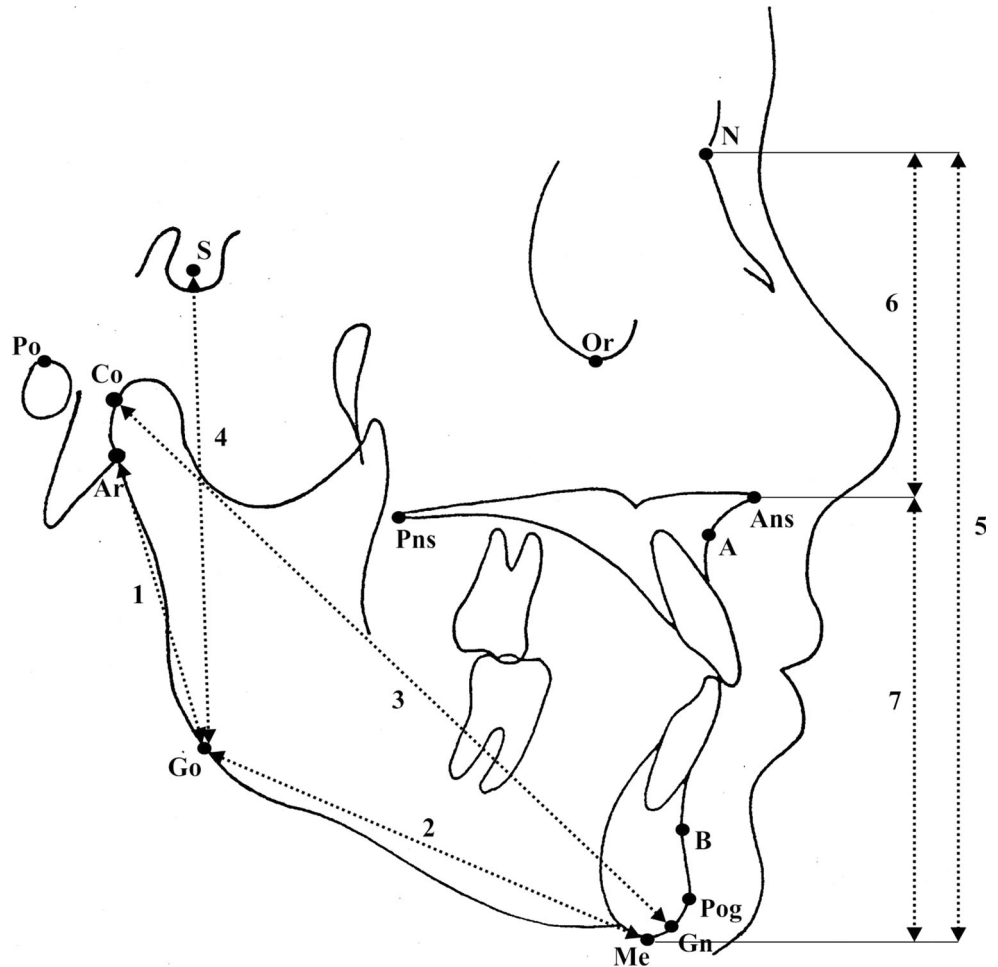
The cephalometric images were recorded using a digital CRANEX D Digital X-ray unit (73 kV, 10 mA, 17.6 s, CC-detector sensor; Soredex, Tuusula, Finland). The first author measured all images using the NemoCeph 2D software (Nemotec, Madrid, Spain). Hard tissue points were used as landmarks during cephalometric analysis, with the reference planes consisting of the Frankfort, mandibular, and cranial base planes (Table 1). Seven linear and fifteen angular parameters were used for sagittal skeletal analysis. All parameters are shown in Figs. 3 and 4.

The cephalometric images of 25 randomly selected participants were measured again after 30 days to evaluate the level of observational error of the examiner. The Dahlberg's formula was used to assess method errors. Of the 15 angular parameters, the errors ranged from 0.2° (of ANB angle) to 1.5° (of S–Ar–Go angle); of the 7 linear

Table 1 Cephalometric landmarks: reference planes and angular/linear parameters

Landmark	
A	Subspinale: the most concave point of the anterior maxilla
Ans	Anterior nasal spine
Ar	Articulare: the junction between the inferior surface of the cranial base and the posterior border of the ascending rami of the mandible
B	Supramentale
Co	Condylion: the most posterior and superior point on the mandibular condyle
Gn	Gnathion: the point located perpendicular on mandibular symphysis, midway between the Pogonion and Menton points
Go	Gonion: the most posterior inferior point on the angle of the mandible
Me	Menton: the most inferior point on the chin
N	Nasion: the middle point of the junction of the frontal and two nasal bones
Or	Orbitale: the lowermost point in the lower margin of the bony orbit
Pns	Posterior nasal spine: the posterior limit of the bony palate of the maxilla
Pog	Pogonion: the most anterior point of the mandibular symphysis
Po	Porion: the central point on the upper margin of the external auditory meatus
S	Sella: the midpoint of the sella turcica
Reference plane	
Frankfort horizontal plane (FH)	Po–Or line projected to form a plane
Mandibular plane (MP)	Go–Me line projected to form a plane
True vertical line (TVL)	The line was drawn vertically through the Nasion point
Cranial base plane (S–N)	S–N line projected to form a plane
Angle	
N–S–Ar (Saddle angle)	The angle between the N–S and S–Ar lines
N–A to FH	The angle formed by the N–A line and Po–Or line
SNA	The angle between the S–N and N–A lines
SNB	The angle between the S–N and N–B lines
SNPog	The angle between the S–N and N–Pog lines
N–Pog to FH	The angle formed by N–A line and Po–Or line
ANB	The angle between the A–N and N–B lines
MP to Palatal plane	The angle formed by Go–Me and Ans–Pns lines
MP to S–N	The angle formed by Go–Me and S–N line
MP to FH	The angle formed by Go–Me line and Po–Or line
S–Ar–Go (Articular angle)	The angle between the S–Ar and Ar–Go lines
Ar–Go–Me (Gonial angle)	The angle between the Ar–Go and Go–Me lines
Ar–Go–N (Upper gonial angle)	The angle between the Ar–Go and Go–N lines
N–Go–Me (Lower gonial angle)	The angle between the N–Go and Go–Me lines
Ar–Go to N–S (Ramus inclination)	The angle formed by Ar–Go and N–S lines
Linear parameters (mm)	
Ar–Go	Ramus height
Go–Me	Mandibular body length
Co–Gn	Effective mandibular length
S–Go	Posterior facial height
N–Me	Anterior facial height
N–Ans	Upper anterior facial height
Ans–Me	Lower anterior facial height
S–Go/N–Me (%)	Facial height ratio
Ans–Me/N–Me (%)	Lower anterior facial ratio

Fig. 3 Linear parameters used in the cephalometric analysis: (1) Ar–Go, (2) Go–Me, (3) Co–Gn, (4) S–Go, (5) N–Me, (6) N–Ans, (7) Ans–Me



parameters, errors ranged from 0.4 mm (of N–Me) to 0.8 mm (of Co–Gn).

Statistical Analysis

Data entry and statistical analysis were performed using SPSS Statistics for Windows, Version 17.0 (SPSS Inc., Chicago, Illinois, USA). The Student's *t* test was used to determine significant variations of cephalometric parameters related to TMD signs. The Bonferroni test was used to compare cephalometric parameters between the Eichner classes. The confidence level of 95% and a two-sided *P* value of < 0.05 were used to reveal significant differences.

Results

Of the 300 elderly aged 65–74 years, 56 subjects failed to participate in the study, the final sample consisted of 122 females and 122 males. Of the final sample, 10.3% had limited mouth opening (< 40 mm), 49.6% TMJ crepitus,

16.3% TMJ tenderness, and 24.2% muscle tenderness. Regarding Eichner's classification, 45.5% of the sample were Class A, 38.5% Class B, and 16.0% Class C (Table 2).

Table 3 shows the angular and linear skeletal differences between the three Eichner classes. Multiple comparisons using Bonferroni test also indicated that Class C had SNB angle, S–N–Pog angle, and the angle formed by N–Pog to the Frankfort plane statistically larger compared to those of Class A and Class B ($P < .001$). No other parameter was significantly different among the three classes ($P > .05$): saddle angle (N–S–Ar), SNA, angle gonial angle (Ar–Go–Me), ramus height (Ar–Go), mandibular body length (Go–Me), and effective mandibular length (Co–Gn). However, the lower gonial angle (N–Go–Me), articular angle (S–Ar–Go), mandibular plane to S–N, and mandibular plane to Frankfort plane of both Class A and Class B were statistically larger than those of Class C ($P < .001$).

Of the linear parameters, anterior facial height (N–Me) and lower anterior facial height (Ans–Me) were statistically different between the three classes ($P < .001$).

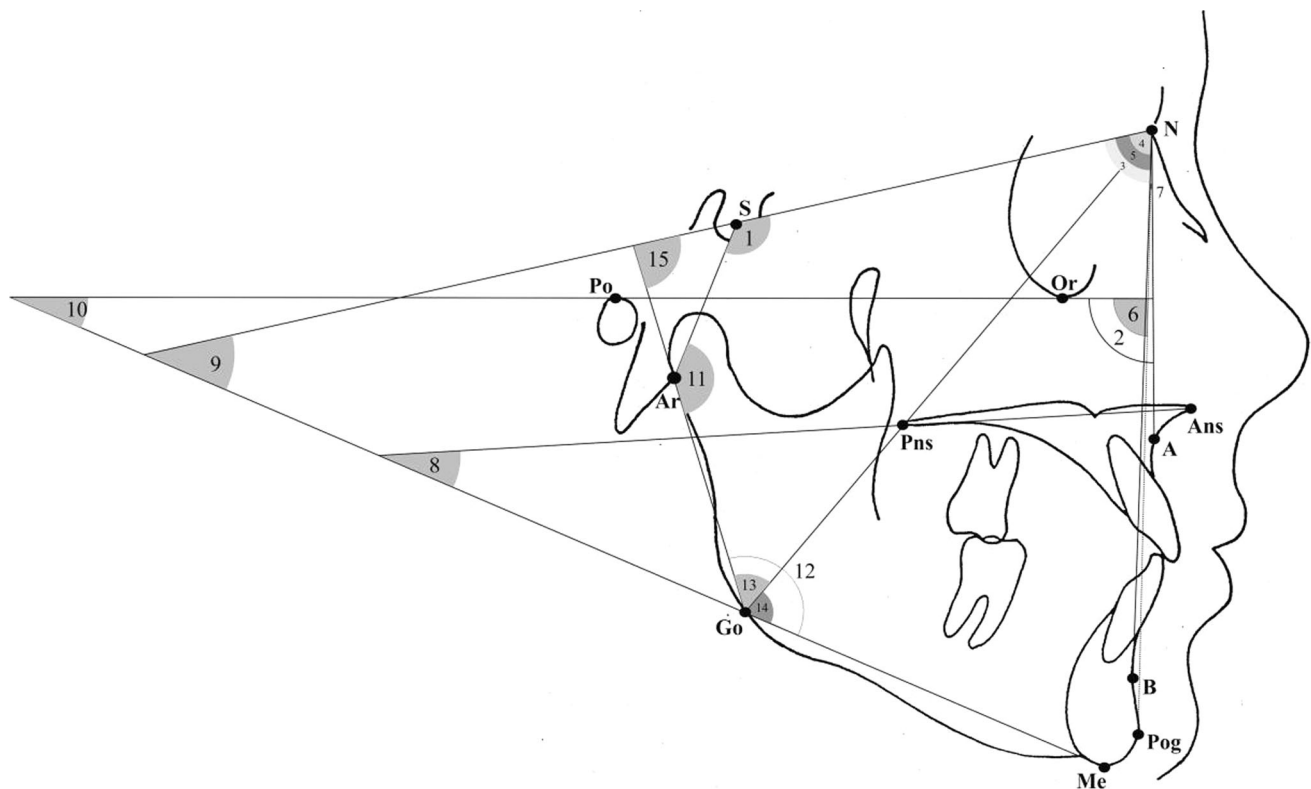


Fig. 4 Angular parameters used in the cephalometric analysis: (1) N–S–Ar, (2) N–A to the Frankfort plane, (3) SNA, (4) SNB, (5) SNPog, (6) N–Pog to FH, (7) ANB, (8) Ans–Pns to the mandibular plane, (9)

mandibular plane to S–N, (10) mandibular plane to the Frankfort plane, (11) S–Ar–Go, (12) Ar–Go–Me, (13) N–Go–Me, (14) N–Go–Me, (15) Ar–Go to N–S

Posterior facial height (S–Go) of Class C was significantly shorter than those of Class A or Class B ($P < .001$). Facial height ratio (S–Go/N–Me) and lower anterior facial height ratio (Ans–Me/N–Me) of Class C were statistically different compared to Class A and Class B ($P = .014$ and $P < .001$, respectively).

Table 4 shows the correlations between cephalometry values and TMD signs. Limited mouth opening was significantly associated with a small angle formed by N–Pog to the Frankfort plane ($P = .020$), and large ANB angle ($P = .035$). TMJ crepitus significantly associated with large angles of: S–N–Pog ($P = .039$), ANB ($P = .001$), the angle formed by N–Pog to the Frankfort plane ($P = .036$), and the upper gonial angle (Ar–Go–N, $P = .023$).

TMJ tenderness was found statistically associated with a short effective mandibular length (Co–Gn, $P = .014$), a short anterior facial height (N–Me, $P = .003$), small angles between: mandibular plane and palatal plane ($P = .009$), mandibular plane and S–N ($P = .048$), and mandibular plane the Frankfort plane ($P = .017$). Participants with muscle tenderness had a large upper gonial angle (Ar–Go–N, $P = .024$) but small lower gonial angle (N–Go–Me, $P = .025$). Lower anterior facial ratio (Ans–Me/N–Me) was significantly associated with a limited mouth opening

($P = .042$), TMJ crepitus ($P = .027$), and TMJ tenderness ($P = .002$).

Discussion

The main findings of the current study indicate that craniofacial structure alterations among elderly Vietnamese are related to reduced occlusal support and TMD signs. Participants without any occlusal support had a significantly different mandibular protrusion; they had larger S–N–Pog angle, and larger angle formed by N–Pog line and the Frankfort plane than those having occlusal support. Owing to the lack of any occlusal support zone, the mandible has to adapt to a new functional position for masticatory performance. Merrot et al. [9] performed a comparison of the changes to the mandible between dentate and edentate subjects and found a reduced symphysis height among the edentate group, which could possibly lead to a change to the protrusive position of the Pogonion point.

The results of the current study seem to confirm that edentulous subjects had substantial morphological changes of craniofacial structure, especially in the mandible, between Class A, Class B, and Class C. Participants with Class C had significantly decreased ramus inclination (Ar–

Table 2 Prevalence of TMD signs and Eichner's classes among elderly Vietnamese ($N = 244$)

Variables	Number	Percent
Gender		
Female	122	50.0
Male	122	50.0
Residence		
Rural	115	47.1
Urban	129	52.9
Limited mouth opening (< 40 mm)		
Yes	25	10.3
No	219	89.7
TMJ crepitus		
Yes	121	49.6
No	123	50.4
TMJ tenderness		
Yes	40	16.3
No	204	83.7
Muscle tenderness		
Yes	59	24.2
No	185	75.8
Eichner's classes		
Class A	111	45.5
Class B	94	38.5
Class C	39	16.0

Go to N–S) and larger upper gonial angle (Ar–Go–N) compared to those of Class A and Class B. This suggests that the mandibular ramus rotates in an anti-clockwise direction. Moreover, accompanied by decreased occlusal vertical dimension, Class C participants had significantly smaller angles formed by the mandibular plane with the cranial base, palatal, and Frankfort planes. These findings are consistent with the findings of other cephalometry investigations among elderly populations [7, 8].

Our study demonstrated that the gonial angle (Ar–Go–Me) of Class C did not differ as compared to Class A and Class B; however, Class C participants had significantly larger upper gonial angle than those of Class A and Class B. It could be explained by the fact that missing posterior teeth caused mandibular bone resorption, especially in mandibular angle; therefore, the gonial tends to rapidly increase after tooth extraction. Our finding is in accordance with the study by Okşayan et al. [20], but contrasts with other studies that reported edentulous subjects having a gonial angle larger than dentate ones [8–10]. This was probably due to the Class C participants in our study having several natural teeth or stumps that had not been extracted.

In a comparison of all cephalometric parameters between participants with occlusal support (Class A or Class B) and those without (Class C), we found significant differences in linear distances in term of lower anterior facial height (Ans–Me). The average of the lower anterior facial height of Class C elderly was 54.8 mm, while those of Class A and Class B were 65.7 and 62.7 mm, respectively. No occlusal support seems to cause loss of vertical dimension of occlusion and resulted in a shorter vertical facial height. Rosa et al. [21] found that the average of the lower anterior facial height of edentulous and dentate Brazilians was 62.7 and 72.7 mm, respectively. A study conducted in Japan found that facial height does not change significantly if the elderly person has enough occluding pairs of teeth [22]. No occlusal support also reduces posterior facial height in the current study mainly because of the decreased lower facial height. Being edentulous might result in significantly shorter mandibular symphysis height, ramus height, and mandibular length, and deeper mandibular notch [9, 10, 21].

Cephalometric parameters can also vary within ethnic groups. The average anterior facial height of elderly Vietnamese (N–Me, 116.3 mm) in the current study is shorter than those of elderly Japanese (123.9 mm) and Brazilians (126.0 mm) [21, 22]. Our elderly Vietnamese participants also had a shorter total mandibular length (Co–Gn, 107.6 mm) compared to elderly Caucasians in France (112.6 mm), Finland (128.7 mm), and Brazil (124.2 mm) [7, 9, 21]. In addition, the short ramus height (Ar–Go) and small gonial angle in the elderly of our sample are typical anthropological characteristics of Vietnamese people.

Craniofacial structure changes may cause TMD signs. In the current study, those elderly who suffered from TMJ tenderness had a significantly shorter anterior face heights (N–Me and Ans–Me), and smaller mandibular plane angles compared to non-sufferers. TMJ tenderness has been significantly associated with loss of posterior occlusal support [23]; therefore, persons with TMJ tenderness are at risk of losing the vertical dimension of occlusion, which can result in a shorter anterior face and alterations to the angles formed by the mandibular plane related to the maxillary plane and cranial base plane.

In our sample, those with TMJ tenderness had shorter total mandibular length, which could be explained by the fact that TMJ tenderness may result in ankylosis and inhibit mandibular movement in a clockwise direction. This finding is reinforced by the studies of Ahn et al. [11] and Matsumoto et al. [14] who wrote that TMD patients had a relatively shorter mandibular and progressive mandibular retrusion.

In the current study, participants with TMJ crepitus had a significantly different Pogonion position. Those elderly also had a larger upper gonial, S–N–Pog angle, and angle

Table 3 Cephalometric analyses between Eichner’s classes ($N = 244$)

Cephalometric measurements	Overall		Eichner’s classification						P value	Bonferroni test
			Class A		Class B		Class C			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
<i>Angular parameters (°)</i>										
<i>Cranial base relationships</i>										
Saddle angle [N–S–Ar]	126.3	6.1	126.6	5.8	126.1	6.0	125.6	7.1	.681	
<i>Maxilla to cranial base</i>										
NA to FH	92.0	3.8	92.4	3.8	92.0	3.7	90.6	3.7	.049*	$C < B, B = A$
SNA	84.4	4.2	84.4	4.1	85.0	4.0	83.3	4.9	.096	
<i>Mandible to cranial base</i>										
SNB	79.2	4.1	78.2	3.9	79.5	3.9	81.1	4.7	< .001*	$A = B, B < C$
S–N–Pog	79.9	4.4	78.6	4.1	80.1	3.9	83.0	4.7	< .001*	$A < B < C$
N–Pog to FH	87.4	4.3	86.5	4.1	87.2	3.9	90.4	4.7	< .001*	$A = B, B < C$
<i>Relationship of maxilla to mandible</i>										
ANB	5.3	3.1	6.2	2.2	5.5	2.4	2.2	4.3	< .001*	$C < B, B = A$
Mandibular plane to Palatal plane	21.1	6.2	22.2	5.9	21.2	5.7	17.4	6.6	< .001*	$C < B, B = A$
<i>Mandibular relationships</i>										
Mandibular plane to S–N	34.0	6.5	35.6	5.8	33.9	6.1	29.4	7.2	< .001*	$C < B, B = A$
Mandibular plane to FH	26.4	6.3	27.7	5.8	26.7	6.0	22.1	6.9	< .001*	$C < B, B = A$
Articular angle [S–Ar–Go]	146.7	8.2	148.8	7.7	146.4	7.1	141.6	9.6	< .001*	$C < B, B = A$
Gonial angle [Ar–Go–Me]	119.7	7.2	118.9	7.5	119.9	6.9	121.2	6.8	.225	
Upper gonial angle [Ar–Go–N]	46.6	4.8	44.8	4.2	46.7	4.0	51.4	5.1	< .001*	$A < B < C$
Lower gonial angle [N–Go–Me]	73.1	5.5	74.2	5.4	73.1	5.1	69.9	5.3	< .001*	$C < B, B = A$
Ramus inclination [Ar–Go to N–S]	93.2	6.5	95.6	6.0	92.8	5.4	87.4	6.2	< .001*	$C < B < A$
<i>Linear parameters (mm)</i>										
Ramus height [Ar–Go]	49.3	5.4	49.9	5.2	49.3	5.2	47.9	5.7	.139	
Mandibular body length [Go–Me]	68.7	5.2	69.1	5.7	68.5	5.1	68.2	4.3	.525	
Total mandibular length [Co–Gn]	107.6	6.2	108.3	6.4	107.4	6.0	105.9	6.0	.109	
Posterior facial height [S–Go]	75.4	6.6	76.8	6.5	75.2	6.5	72.0	6.1	< .001*	$C < B, B = A$
Anterior facial height [N–Me]	113.0	8.7	116.3	7.7	112.5	7.8	104.8	7.8	< .001*	$C < B < A$
Upper anterior facial height [N–Ans]	50.2	3.5	50.5	3.3	49.8	3.5	50.0	3.8	0.339	
Lower anterior facial height [Ans–Me]	62.8	7.5	65.7	6.6	62.7	6.1	54.8	7.2	< .001*	$C < B < A$
Facial height ratio % [S–Go/N–Me]	66.9	5.2	66.1	4.6	67.0	5.2	68.9	6.1	.014*	$A = B, B < C$
Lower anterior facial ratio % [Ans–Me/N–Me]	55.5	3.2	56.5	2.7	55.6	2.5	52.1	4.1	< .001*	$C < B, B = A$

* Significant

formed by N–Pog to the Frankfort plane, but presented a smaller ANB angle, and reduced the lower facial height ratio, compared to the participants without TMJ crepitus. It is possible that there is the growth of the protrusion and anti-clockwise rotation of the mandible, leading to the Pogonion point moving upward and forward. Our finding contrasts with the study by Matsuo et al. [15] where TMJ crepitus was significantly associated with retrusion of the mandible; this could be due to Matsuo’s sample only including participants with Angle Class II malocclusion. Moreover, crepitus often indicates TMJ arthritis and is associated with edentulousness and advancing age [24].

Wiese et al. [25] concluded that crepitus is often accompanied by osseous changes of the TMJ, such as flattening, erosion, osteophytes, and sclerosis. Therefore, the alteration in the craniofacial structure could lead to crepitus.

Muscle tenderness was found to significantly associate with a small lower gonial mandible (N–Go–Me) in the current study. The temporalis and masseter muscles are powerful masticatory muscles, and when muscle tenderness occurs, mandible could be retracted upward that caused alteration to the gonial mandible and consequently shorter anterior facial height.

Table 4 Cephalometric parameters significantly associated with TMD signs ($N = 244$)

Parameter	TMD sign				<i>P</i> value*
	Yes		No		
	Mean	SD	Mean	SD	
Limited mouth opening (< 40 mm)					
N–Pog to FH (°)	85.5	4.8	87.7	4.2	.020
ANB (°)	6.5	2.3	5.1	3.1	.035
Ans–Me/N–Me (%)	56.7	2.3	55.3	3.3	.042
Muscle tenderness					
Ar–Go–Me (°)	117.8	6.9	120.3	7.2	.024
N–Go–Me (°)	71.7	4.9	73.5	5.6	.025
TMJ crepitus					
S–N–Pog(°)	80.5	4.6	79.3	4.1	.039
N–Pog to FH (°)	87.9	4.7	86.8	3.9	.036
ANB (°)	4.6	3.4	5.9	2.4	.001
Ar–Go–N (°)	47.3	5.1	45.9	4.4	.023
Ans–Me/N–Me (%)	54.9	3.3	55.9	3.1	.027
TMJ tenderness					
MP to Palatal (°)	18.7	5.6	21.5	6.2	.009
MP to S–N (°)	32.1	6.2	34.3	6.5	.048
MP to FH (°)	24.5	5.0	26.8	6.5	.017
N–Go–Me (°)	70.9	5.3	73.5	5.4	.006
Co–Gn (mm)	105.4	5.6	108.0	6.2	.014
N–Me (mm)	109.3	6.7	113.7	8.5	.003
Ans–Me (mm)	59.2	7.8	63.5	7.2	.001
Ans–Me/N–Me (%)	53.9	3.8	55.7	3.1	.002

* Student's *t* test, significance of $P < .05$

The elderly participants with a limited mouth opening had significantly larger ANB angle and smaller angle formed by N–Pog and the Frankfort plane compared to those with a mouth opening of ≥ 40 mm. These characteristics might be explained by limited mouth opening resulting in mandibular retrusion. Limited mouth opening can be associated with myofascial pain; therefore, the mandible of such subjects has to be retruded to adapt the function of movement.

In addition, mouth-opening limitation is also a sign of osteoarthritis that related to the osseous changes of the TMJ condyle such as erosion and fattening. Several studies have demonstrated that TMJ osteoarthritis was observed more often among TMD patients with a facial skeletal pattern of Class II malocclusion [26], and such patients often had a smaller SNB, larger ANB, and shorter ramus height [27]. Therefore, participants with limited mouth opening in our study might have osseous changes of the condyle that caused change position of the mandible.

In summary, the results showed that craniofacial structures had significant differences between Class A (4

occlusal support zones), Class B (1–3 occlusal support zones), and Class C (no occlusal support zone) participants such as: an increased upper gonial angle and S–N–Pog angle; a decreased ramus inclination and shorter anterior facial height. The TMD signs of limited mouth opening, TMJ tenderness, TMJ crepitus, and muscle tenderness were found to significantly associate with alteration in the craniofacial structures.

The current study has several limitations. We compared craniofacial structure changes of different types of occlusal support according to Eichner classification; however, we did not perform a follow-up study to observe changes of structures on the same person who lost occlusal support from Class A to Class C. Lateral cephalogram is often used to measure craniofacial structures based on two dimensional radiographic image, but not for detailed analysis of minor osseous changes of temporomandibular joint structure. A cone beam computed tomography or magnetic resonance imaging should be used for more accurate analysis of TMJ; however, medical center of current study had not been equipped with those radiographic devices yet.

Conclusion

Among elderly Vietnamese, the alteration of craniofacial structures was significantly associated with TMD signs. The higher number of lost occlusal support zones, the more significant the changes to elderly's craniofacial structure.

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Compliance with Ethical Standards

Conflict of interest None of the authors have a conflict of interest to declare.

References

1. Ikebe K, Hazeyama T, Iwase K, Sajima H, Gonda T, Maeda Y et al (2008) Association of symptomless TMJ sounds with occlusal force and masticatory performance in older adults. *J Oral Rehabil* 35:317–323
2. Schmitter M, Rammelsberg P, Hassel A (2005) The prevalence of signs and symptoms of temporomandibular disorders in very old subjects. *J Oral Rehabil* 32:467–473
3. Gesch D, Bernhardt O, Alte D, Schwahn C, Kocher T, John U et al (1985) Prevalence of signs and symptoms of temporomandibular disorders in an urban and rural German population:

- results of a population-based Study of Health in Pomerania. *Quintessence Int Berl Ger* 2004(35):143–150
4. Moreno-Hay I, Okeson JP (2015) Does altering the occlusal vertical dimension produce temporomandibular disorders? A literature review. *J Oral Rehabil* 42:875–882
 5. Hiltunen K, Vehkalahti M, Ainamo A (1997) Occlusal imbalance and temporomandibular disorders in the elderly. *Acta Odontol Scand* 55:137–141
 6. Tavano KTA, Seraidarian PI, de Oliveira DD, Jansen WC (2012) Determination of vertical dimension of occlusion in dentate patients by cephalometric analysis—pilot study. *Gerodontology* 29:e297–e305
 7. Brzoza D, Barrera N, Contasti G, Hernández A (2005) Predicting vertical dimension with cephalograms, for edentulous patients. *Gerodontology* 22:98–103
 8. Huuonen S, Sipilä K, Haikola B, Tapio M, Söderholm A-L, Remes-Lyly T et al (2010) Influence of edentulousness on gonial angle, ramus and condylar height. *J Oral Rehabil* 37:34–38
 9. Merrot O, Vacher C, Merrot S, Godlewski G, Frigard B, Goudot P (2005) Changes in the edentate mandible in the elderly. *Surg Radiol Anat* 27:265–270
 10. Uma M, Shetty R, Shenoy KK (2013) Cephalometric: evaluation of influence of edentulousness on mandibular morphology: a comparative study. *J Indian Prosthodont Soc* 13:269–273
 11. Ahn SJ, Baek SH, Kim TW, Nahm DS (2006) Discrimination of internal derangement of temporomandibular joint by lateral cephalometric analysis. *Am J Orthod Dentofacial Orthop* 130:331–339
 12. Chen S, Lei J, Fu KY, Wang X, Yi B (2015) Cephalometric analysis of the facial skeletal morphology of female patients exhibiting skeletal class II deformity with and without temporomandibular joint osteoarthritis. *PLoS ONE* 10:e0139743
 13. Emshoff R, Moriggl A, Rudisch A, Brunold S, Neunteufel N, Crismani A (2011) Cephalometric variables discriminate among magnetic resonance imaging-based structural characteristic groups of the temporomandibular joint. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 112:118–125
 14. Matsumoto R, Ioi H, Nishioka M, Goto TK, Nakata S, Nakasima A et al (2006) TMJ osteoarthritis/osteoarthritis and dentofacial morphology in Japanese females. *Orthod Waves* 65:101–106
 15. Matsuo Y, Kajii TS, Yasunaga M, Sakaguchi Y, Tamaoki S, Ishikawa H (2016) Characteristics of maxillofacial morphology of angle class II patients with temporomandibular disorders involving crepitus. *Orthod Waves* 75:27–34
 16. Xie Q, Yang C, He D, Cai X, Ma Z, Shen Y et al (2016) Will unilateral temporomandibular joint anterior disc displacement in teenagers lead to asymmetry of condyle and mandible? A longitudinal study. *J Cranio-Maxillofac Surg* 44:590–596
 17. Selaimen CMP, Jeronymo JCM, Brilhante DP, Lima EM, Grossi PK, Grossi ML (2007) Occlusal risk factors for temporomandibular disorders. *Angle Orthod* 77:471–477
 18. Schiffman E, Ohrbach R, Truelove E, Look J, Anderson G, Goulet J-P et al (2014) Diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications: recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. *J Oral Facial Pain Headache* 28:6–27
 19. Eichner K (1990) Renewed examination of the group classification of partially edentulous arches by Eichner and application advices for studies on morbidity statistics. *Stomatol DDR* 40:321–325
 20. Okşayan R, Asarkaya B, Palta N, Şimşek İ, Sökücü O, İşman E (2014) Effects of edentulism on mandibular morphology: evaluation of panoramic radiographs. *Sci World J* 2014:254932
 21. Rosa WGN, de Lima Navarro R, de Castro Ferreira Conti AC, de Almeida MR, Oltramari-Navarro PVP (2015) Assessment of cephalometric characteristics in the elderly. *Braz Oral Res* 29:1–9
 22. Shimizu T, Motegi E, Nomura M, Kaneko Y, Takeuchi F, Yamaguchi T et al (2006) Cephalometric study of elderly with nearly intact dental arches. *Gerodontology* 23:60–63
 23. Türp JC, Schindler H (2012) The dental occlusion as a suspected cause for TMDs: epidemiological and etiological considerations. *J Oral Rehabil* 39:502–512
 24. Sipilä K, Nääpänkangas R, Könönen M, Alanen P, Suominen AL (2013) The role of dental loss and denture status on clinical signs of temporomandibular disorders. *J Oral Rehabil* 40:15–23
 25. Wiese M, Svensson P, Bakke M, List T, Hintze H, Petersson A et al (2008) Association between temporomandibular joint symptoms, signs, and clinical diagnosis using the RDC/TMD and radiographic findings in temporomandibular joint tomograms. *J Orofac Pain* 22:239–251
 26. Krisjane Z, Urtane I, Krumina G, Neimane L, Ragovska I (2012) The prevalence of TMJ osteoarthritis in asymptomatic patients with dentofacial deformities: a cone-beam CT study. *Int J Oral Maxillofac Surg* 41:690–695
 27. Ioi H, Matsumoto R, Nishioka M, Goto TK, Nakata S, Nakasima A et al (2008) Relationship of TMJ osteoarthritis/osteoarthritis to head posture and dentofacial morphology. *Orthod Craniofac Res* 11:8–16