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ORIGINAL ARTICLE

The relationship between facial morphology and the structure of the alveolar part of the mandible in edentulous complete denture wearers. A preliminary study

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Abstract

Objective. Although the effect of involutional processes that occurs in the maxilla and mandible of edentulous subjects is obvious, the problem of factors definitely determining the direction of changes still remains unsolved. This study was aimed at determining the relationship between facial morphology and the structure of the alveolar part and the body of the mandible in edentulous complete denture wearers. ***Materials and methods.*** Twenty-five healthy edentulous Caucasian patients in the 70.5 ± 9 years of age group were examined. All patients underwent tele-X-ray examination with the presence of currently used dentures in the oral cavity. To assess morphological parameters of the facial skeleton, cephalograms were analyzed according to Ricketts and Mc Namara method. To assess the mandible morphology, the films were measured using the method of Tallgren. ***Results.*** The period of edentulism was found to be negatively correlated with the anterior segment of the body of the mandible within its symphysis. The parameter corresponding to the location of the first lower molar showed a directly proportional correlation with G'-Sn', G'-Me', Sn'-Me', N-Ans, N-Me, Ans-Me, Co-Gn and Co-Go. Positive correlations were found between the parameters describing contour of the alveolar part of the body of the mandible and mandibular symphysis and G'-Me', Sn'-Me', N-Me, Ans-Me describing the height of the occlusal vertical dimension. ***Conclusion.*** The study showed a directly proportional correlation between the vertical occlusal dimension of the lower face conditioned by prosthetic rehabilitation and the height of the alveolar part in the lateral regions of the mandible.

Key Words: *alveolar bone loss, cephalometry, edentulism, facial morphology*

Introduction

The loss of teeth determines important changes in the masticatory system, which affects bone, oral mucosa, muscles and function [1–4]. Both resorption of the alveolar bone and the reduced formation of new bone is reported, while a decreased number of receptors is found in the overlying mucosa during this process [5–7].

From the prosthetic point of view the vertical height of the bony ridge determines retention and stability of the complete dentures. The shape of the dental arches of the dentulous jaws is phylogenetically conditioned [8–10]. Their width and length are correlated with craniofacial skeletal pattern [11–13].

All the abnormalities associated with horizontal growth of the jaws influence the parameters obtained in complete denture wearers. In addition, long periods of use of prostheses, mechanical injury linked with abnormal delivery, osteoporosis and hormonal changes may increase the observed phenomena [14–16].

Alveolar ridge resorption runs to the middle in the horizontal plane. This is the result of the morphological and histological bone features. In the case of the mandible this process occurs eccentrically (centrifugal) in the posterior area corresponding to the location of molars and premolars, in front of the mandible conversely–concentrically (centripetal) [17,18].

It has been found that mean reduction of the anterior part of the mandible is 4-times greater than that of the upper jaw [13]. Evaluation of the relationship between the atrophied mandible and maxilla reveals an increase of the ratio of mandibular to maxillary width with deepening atrophy [18]. This skeletal disproportion makes prosthetic treatment

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more difficult [8]. The neutral zone moves outside and becomes narrowed. These changes in bone structure are characterized by upward rotation of the mandible (counter-clockwise rotation viewed in right profile) with a subsequent decrease in the occlusal vertical dimension and an increase in the mandibular prognathism [19–22].

Proper morphology of the alveolar processes of the jaws and the alveolar part of the mandible allows planning of prosthetic restorations with the optimum retention and stability satisfying the patient [23]. Although the effect of involutional processes that occurs in the maxilla and mandible of edentulous subjects is obvious, the problem of factors definitely determining the direction of changes still remains unsolved. Therefore, the execution of new prosthetic restorations should be preceded by thorough pre-rehabilitation assessment of the conditions of the prosthetic foundation.

The aim of this study was to determine the relationship between facial morphology and the structure of the alveolar part and the body of the mandible in edentulous complete denture wearers. The height of the mandibular bone in relation to vertical occlusal dimension was explored. The morphology of the mandible was assessed with respect to age, denture wearing time and edentulous period.

Materials and methods

The study group consisted of 25 healthy Caucasian patients (14 females, 11 males) aged 44–86 years (mean = 70.5 ± 9) who were referred to the Department of Prosthetic Dentistry at the Medical University of Bialystok, Poland, to make new dentures. They had worn their existing appliances for over 5 years, but no longer than 15 years (mean = 9.8 ± 5.2). The mean time of edentulism was 17 ± 10 years. Most of the participants had used two sets of dentures prior to their recruitment to the study.

Exclusion criteria

Subjects were excluded from the study when they demonstrated:

(1) Asthma;
(2) Diabetes;
(3) Corticosteroid treatment;
(4) Alcohol addiction;
(5) Combination syndrome;
(6) Anterior hyperfunction syndrome;
(7) Visible asymmetry of the mandible and face;
(8) Hormone therapy;
(9) Overgrowth of the tuberosities;
(10) Papillary hyperplasia of the hard palatal mucosa;
(11) History of trauma;
(12) Osteoporosis; or
(13) Any complaints concerning pain in any region of masticatory system.

Patients received a new conventional complete maxillary and mandibular denture.

Cephalometric X-rays were obtained in the standing posture with head in natural position in the cephalostat and teeth in centric occlusion with a final enlargement of 8–14%. Lateral standardized cephalograms were taken from each subject by a single technician using the same X-ray device and standardized procedure: the distance between the focal spot and the mid-sagittal plane was 152 cm and between the film and the mid-sagittal plane was 10 cm. The values measured were not corrected for linear enlargement.

The radiation dose was 0.15 mSv for each cephalogram. Permanent test conditions were provided in all cases (parameters of exposure: voltage = 57–85 kV, on average of 77 kV, intensity = 2–16 mA with mean value of 12 mA, time of exposure = 0.64 s, dimensions of the film = 18 cm × 24 cm, resolution of image = 0.35–0.5).

Reference points were traced manually on the Canson' s carbon paper (Calque Satin 210 mm × 297 mm A 4, 90 g/m^3 – gsm). A single examiner

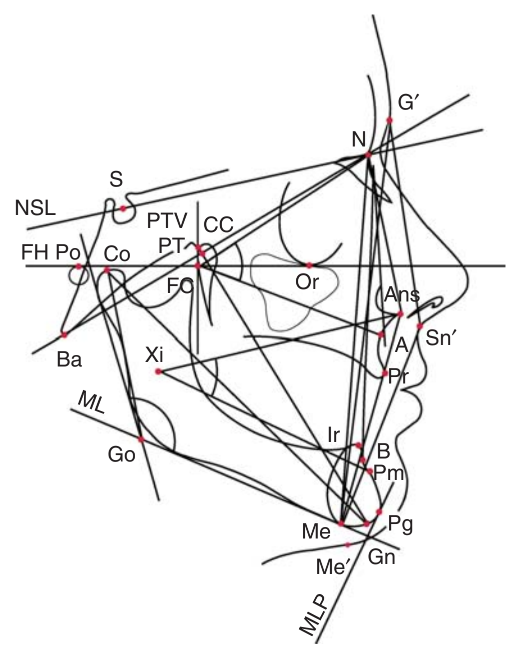

Figure 1. Reference points and lines with regard to the cephalometric analysis according to Ricketts [24–26] and McNamara [27]. A detailed description of the reference points is presented in Table I. G', Glabella; Sn', Subnasale; Me', Soft tissue Menton; A, Subspinale; Pr, Prosthion; ANS, Anterior nasal spine; Sm (B); Supramentale; Ir, Infradentale; Co, Condylion; Gn, Gnathion; Me, Menton; N, Nasion; Or, Orbitale; Pm, Suprapogonion; Po, Porion; S, Sella; Ba, Basion; Pg, Pogonion; Go, Gonion; FC, Facial centre; CC, Centre of the cranium; Xi, Xilion; PTV, Pterygoid vertical; ML, Mandibular plane; MLP, line perpendicular to ML passing through the Pg; NSL, Sella-Nasion plane; FH, Frankfurt plane.

performed all cephalometric measurements. To avoid landmark identification error, the initial localization was re-evaluated by two researchers.

In order to assess chosen morphological parameters of the facial skeleton, cephalograms were analyzed according to the method of Ricketts [24–26] and McNamara [27] (Figure 1). The reference points and lines are presented in Table I.

Linear and angular parameters were investigated. Among those directly related to the occlusal vertical dimension of the lower face, G'-Me', Sn'-Me', N-Me, Ans-Me and Ans-Xi-Pm angle were analyzed. Effective mandibular length was determined by the linear distance from Co to Gn. The length of the ramus of the mandible was specified by Co-Go dimension. The relation between the maxilla and the cranial base was determined by the SNA, NFcA and N-Ans measurements. Estimation of the ANB angle allowed one to monitor changes in the maxillomandibular relationship caused by mandibular posteriorotation or anteriorotation before and after the treatment. To evaluate the position of the mandible to skull base, the SNB angle was assessed. Facial angle was also noted. It means that angular dimension between the Ba-N and PT-Gn lines was measured. Additionally mandibular angle and G'-Sn' distance were evaluated. The

Table I. Reference points and lines according to the method by Ricketts [24–26] and McNamara [27].

Soft tissue cephalometric landmarks	
G'	Glabella: the most anterior soft tissue point of the frontal bone
Sn'	Subnasale: the point at which the nasal septum merges mesially with the upper cutaneous lip in the mid-sagittal plane
Me'	Soft tissue Menton: the point on the lower contour of the chin opposite to the hard tissue Menton
Skeletal/hard tissue cephalometric landmarks	
A	Subspinale: the deepest point in the midsagittal plane between the anterior nasal spine and prosthion
Pr	Prosthion: the point of the upper alveolar process that projects most anteriorly in the midline
ANS	Anterio nasal spine: the anterior point of the nasal floor
B (Sm)	Supramentale: the deepest point in the midsagittal plane between infradentale and Pg
Ir	Infradentale: the most anterior point of the alveolar process of the mandible
Co	Condylion: the most superior posterior point on the outline of the mandibular condyle
Gn	Gnathion: most anterior and lowest point of the symphysis
Me	Menton: the lowest point of the contour of the mandibular symphysis
N	Nasion: most anterior point of nasofrontal suture in the midsagittal plane
Or	Orbitale: the lowest point on the margin of the orbit
Pm	Suprapogonion: point where curvature of the anterior contour of the symphysis changes from concave to convex
Po	Porion: the midpoint on the upper edge of the external auditory meatus
S	Sella: middle point of sella turcica
PT	the junction of the pterygopalatine fossae and foramen rotundum located at the posterosuperior border of the averaged pterygopalatine fossae
Ba	Basion: the lowest point on the anterior medial margin of the foramen magnum in the mid-sagittal plane
Pg	Pogonion: the most anterior point on the symphysis of the mandible
Constructional points	
Go	Gonion: formed by the junction of the ramus with the lower border of the mandibular body on its posteroinferior aspect
FC	Facial centre: intersection of the Frankfort plane and the perpendicular through the posterior side of the pterygomaxillary fissure (PTV)
CC	Centre of the cranium: the point of intersection between the BaN plane and the facial axis (PTGn) plane
Xi	Xilion: the point placed in the centre of the mandibular ascending ramus, determined by the Frankfort plane and pterygomaxillary fissure
Cephalometric planes and lines:	
PTV	Pterygoid vertical: used to represent the posterior border of the maxilla. A line perpendicular to FH and tangent to the posterior contour of the PTM (Pterygomaxillary fossa) at the level of the foramen ovale. Anteroposterior extent of the anterior cranial base. Represents the cranial base in the mid-sagittal plane
ML	Mandibular plane: a line tangent to the most prominent points on the lower border of the mandible
MLP	ML straight line perpendicular to passing through the Pg
NSL	Sella-Nasion plane: anteroposterior extent of the anterior cranial base. Represents the cranial base in the mid-sagittal plane
FH	Porion-Orbitale plane, horizontal plane, Frankfurt plane: represents the cranial base

measurements of all parameters from the Ricketts and McNamara's analysis of the second X-ray (X-ray obtained after prosthetic rehabilitation in the first day of using new dental restorations) correlated with the data obtained from the morphological assessment of the mandible according to Tallgren's method (Figures 2 and 3) [28].

Radiological evaluation performed before and after prosthetic treatment has enabled an objective assessment of the quality of clinical procedures including verification of the vertical occlusal dimension. Changes in parameters providing a favorable distribution of cephalometric values were observed in the case of linear and angular measurements (according to Ricketts and McNamara analysis) as well as proportion of morphological face. For example, the average value of the AnsXiPm angle obtained after rehabilitation fulfil suggested a norm of Ricketts 46° ± 3 prepared on the dentulous subjects [24–26]. Also, in relation to Brzoza et al.'s [29] research conducted in a complete denture wearers group, our results fluctuated in the range of the suggested reference values of 47° ± 4°.

In order to assess the mandible morphology, the films were measured using the method of Tallgren et al. [28] (Figures 2 and 3). According to this the distance between the lower mandibular edge and the top of the alveolar part or the body was assessed in geometrically constructed points. Point md 1 was the point at which the mandibular plane angle bisector crossed the body. Point md 5 was the most dorsal and upward point within the mandibular symphysis. Points md 2, md 3 and md 4 were determined based on the division of the segment |md1md5| into four equal parts. Point md 6 was localized at the uppermost point on the symphysis in relation to ML. Point md 7 was defined at the most superior point on the anterior contour of the alveolar part of the mandible. The location of the B point was also considered (B – Sm – Supramentale – the deepest point in the midsagittal plane between infradentale and Pg). The positions of all points were assessed with respect to ML and MLP reference lines. Additionally the width of the ramus of the mandible (Ra) was noted. For this purpose a tangential straight line was constructed to the outer margin of the ramus ascendens of the mandible. A line perpendicular to this tangent

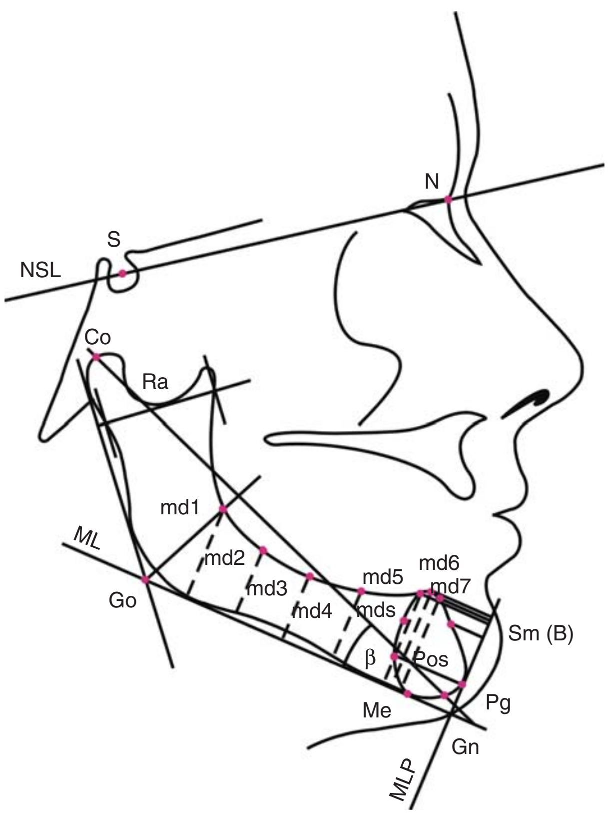

Figure 2. Reference points with regard to the analysis of the morphology of the alveolar part of the mandible according to Tallgren [28]. A detailed description of the reference points is presented in Table I. S, Sella; N, Nasion; Go, Gonion; Sm (B), Supramentale; Co, Condylion; Gn, Gnathion; Me, Menton; Pg, Pogonion; md 1, md 2, md 3, md4, md 5, md 6, md 7, Pos, mds, reference points located within the alveolar part of the mandible and symphysis; Ra, width of the mandibular ramus; Beta angle, the angle between ML plane and mandibular length, Co-Gn; ML, Mandibular plane; MLP, line perpendicular to ML passing through the Pg; NSL, Sella-Nasion plane.

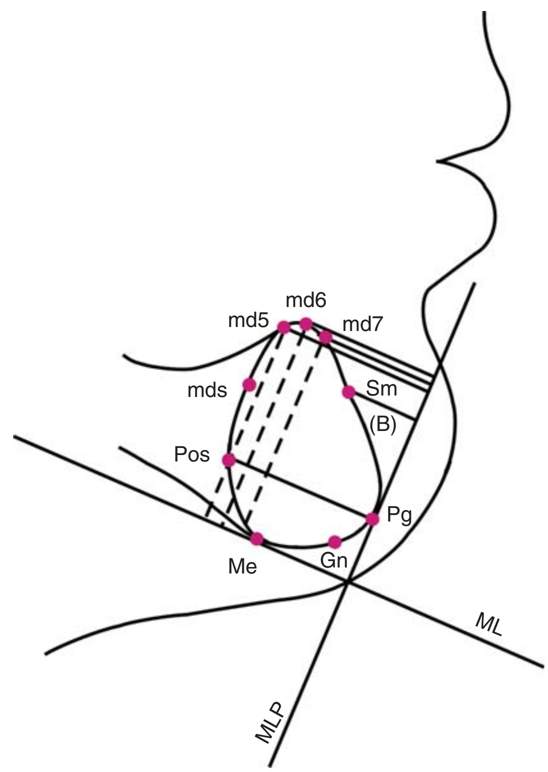

Figure 3. Expanded reference points md 5, md6, md7 and others with regard to the analysis of the morphology of the alveolar part of the mandible according to Tallgren [28]. A detailed description of the reference points is presented in Table I. Sm (B), Supramentale; Gn, Gnathion; Me, Menton; Pg, Pogonion; md 5, md 6, md 7, Pos, mds, reference points located within the alveolar part of the man-dible and symphysis; ML, Mandibular plane; MLP, line perpendicular to ML passing through the Pg.

Table II. Correlations of morphological parameters of the mandible (according to Tallgren [28]) with age, complete denture wearing time and the edentulous period (columns in the table contain Pearson's correlation coefficient *r*).

Morphological parameters characterizing the alveolar part of the mandible according to Tallgren [28]	Age	Denture wearing time	Edentulous period
Orientation with respect to ML reference line			
md1	0.17	0.11	0.42*
md2	−0.42	−0.23	0.11
md3	−0.60	−0.33	−0.12
md4	−0.56	−0.22	−0.29
md5	−0.66	−0.34	−0.42*
md6	−0.63	−0.32	−0.37
md7	−0.66	−0.38	−0.34
Sm (B)	−0.63	−0.44	−0.33
Orientation with respect to MLP reference line			
md5	−0.41	−0.22	0.17
md6	−0.58	0.02	−0.31
md7	−0.64	−0.07	−0.32
Sm (B)	−0.15	−0.22*	−0.10
Others			
Pos-Pg	−0.14	−0.14	0.17
mds-Sm (B)	−0.16	−0.35	0.16
Ra	0.03	−0.05	−0.06
β angle	0.01	0.06	−0.40*

* $p < 0.05$ statistical significance.

was drawn at the lower margin of incisura semilunaris of the mandible. The distance between anatomic borders of ramus ascendens of the mandible represented its width (Ra) (Figure 2).

Anteroposterior dimension of the symphysis (mds – Sm(B), Pos-Pg) was also assessed. Point mds was traced on the posterior contour of mandibular symphysis as the mid-point between point Pos and md 5. Point Pos was localized as the intersection between the posterior contour of mandibular symphysis and a line through Pg parallel to ML. Additionally, β, the angle between ML and mandibular length (Co-Gn), was considered.

Mean values and ± SD of the above-mentioned morphological parameters of the alveolar part of the mandible (md1→md7, Sm(B), Pos-Pg, mds-Sm(B)) according to Tallgren's analysis were calculated [28]. Correlations of morphological parameters of the mandible with age, complete denture wearing time and edentulous period were taken.

The study results were subjected to statistical analysis using the Statistica 7.0 PL software. Three evaluations were calculated for each followed parameter. Obtained values were averaged. Measure of central tendency (including arithmetic mean) and measures of variation (standard deviation) were used to evaluate the distribution of quantitative variables. The strength of the relationship between tested parameters was determined using Pearson's correlation coefficient and its significance was assessed using the *t*-test for the correlation coefficient. Differences and relationships were considered to be statistically significant at $p < 0.05$.

The protocol was approved by the Institutional Bioethic Committee at the Medical University of Bialystok in Poland; the number of the approval: R-I-002/88/2008. Written consent was obtained from the patients.

Results

There was no statistically significant difference between the values of the morphological parameters of the mandible (md1→md7, Sm(B), Pos-Pg, mds-Sm(B)) derived on the beginning of the therapy (with the presence of currently used dentures in the oral cavity) and 6–8 weeks later after rehabilitation (on the first day of using new dental restorations). Evaluated variables were comparable.

Statistical analysis showed no significant ($p < 0.05$) correlations between morphological parameters of the mandible and age of the patients (Table II). The period of edentulism was found to be negatively

Table III. Mean values (mm) of morphological parameters of the alveolar part of the mandible according to Tallgren [28].

Morphological parameters characterizing the alveolar part of the mandible according to Tallgren [28]	Mean values (SD), mm
Orientation with respect to ML reference line	
md1	31.97 (3.02)
md2	21.64 (2.66)
md3	16.60 (4.17)
md4	16.84 (6.23)
md5	21.82 (5.03)
md6	23.50 (5.72)
md7	23.77 (5.67)
Sm (B)	22.47 (4.87)
Orientation with respect to MLP reference line	
md5	16.99 (2.59)
md6	13.76 (3.22)
md7	10.67 (4.07)
Sm (B)	12.12 (4.19)
Others	
Pos-Pg	15.31 (1.96)
mds-Sm (B)	10.41 (2.64)
Ra	38.89 (3.33)
β angle	21.22 (3.66)

correlated with the md5/ML and β-angle. The strength of the relationships was low. A positive less significant relation was found between md1/ML and the time of toothlessness (Table II).

The lowest mean value in the group of mandibular body morphology indices with regard to ML reference (tangent to the mandibular base plane) was observed at md 3, i.e. at the site of the first lower molar and forward, in its direct vicinity, at md4 (Table III). The distribution of the values md1→md7/ML is reflected in the shape of the curve of Spee of natural dentition. Usually first molars are situated in the deepest point of this curve.

For the MLP plane the lowest value was noted for md7, being most upward within the anterior contour of the mandibular symphysis (Table III). The dimension values for Pos-Pg (vestibulolingual cross-section of the chin) and Ra (width of the mandibular ramus at its incisure) were observed to be relatively constant (low SD value) (Table III).

Table IV presents mutual implications of linear cephalometric and morphological indices of the mandible. The md 3 parameter corresponding to the location of the first lower molar shows a directly proportional correlation with all linear parameters according to the analysis of Ricketts [24–26] and McNamara [27], i.e. G'-Sn', G'-Me', Sn'-Me', N-Ans, N-Me, Ans-Me, Co-Gn and Co-Go. Positive correlations were also found between the parameters md2→md7/ML and G'-Me', Sn'-Me', N-Me, Ans-Me describing the height of the occlusal vertical dimension.

Table V shows correlations of morphological parameters of the mandible (according to Tallgren [28]) and cephalometric angular parameters (according to Ricketts [24–26] and McNamara [27]). Worthy of note are the implications concerning the angular parameter Ans-Xi-Pm characterizing the occlusal vertical dimension as well as the morphological parameters md2→md7/ML.

Discussion

The present study revealed a lack of correlation between the age of study subjects and the morphological parameters of the mandible. These observations seem to be associated with the findings reported by Tallgren [13].

The morphology of the mandible is determined by anatomical and functional factors, also consequences of using complete dentures. Despite current knowledge, the magnitude of the alveolar resorption shows great individual variations.

Table IV. Correlations of cephalometric parameters (according to Ricketts [24–26] and McNamara [27]) with morphological parameters (according to Tallgren [28]) of the alveolar part of the mandible (columns in the table contain Pearson's correlation coefficient *r*).

	Linear parameters according to Ricketts [24–26] and McNamara [27] method							
Morphological parameters according to Tallgren [28]	G'-Sn'	G'-Me'	Sn'-Me	N-Ans	N-Me	Ans-Me	Co-Gn	Co-Go
Orientation with respect to ML reference line								
md1	0.23	0.07	−0.03	0.30	0.08	−0.01	−0.01	0.19
md2	0.69*	0.60*	0.48*	0.43*	0.65*	0.55*	0.44*	0.40
md3	0.68*	0.69*	0.69*	0.42*	0.76*	0.69*	0.59*	0.44*
md4	0.61*	0.72*	0.75*	0.41*	0.74*	0.69*	0.59*	0.31
md5	0.70*	0.80*	0.82*	0.29	0.76*	0.76*	0.69*	0.30
md6	0.68*	0.80*	0.81*	0.30	0.76*	0.77*	0.68*	0.28
md7	0.71*	0.79*	0.75*	0.29	0.74*	0.73*	0.67*	0.21
Sm (B)	0.58	0.72*	0.70*	0.13	0.66*	0.70*	0.63*	0.27
Orientation with respect to MLP reference line								
md5	0.40	0.38*	0.21	0.29	0.43*	0.31	0.37	0.33
md6	0.37	0.47*	0.39	0.18	0.51*	0.45*	0.53*	0.49*
md7	0.54	0.68*	0.57*	0.35	0.68*	0.56*	0.73*	0.15
Sm (B)	0.15	0.28	0.26	−0.41*	0.20	0.41*	0.11	0.04
Others								
Pos-Pg	0.04	0.15	0.16	−0.05	0.09	0.10	0.19	0.29
mds-Sm (B)	0.44	0.43*	0.34	0.09	0.31*	0.33	0.28	−0.04
Ra	0.15	0.01	−0.04	0.21	−0.08	−0.18	0.11	0.00
β angle	0.03	0.04	0.09	−0.03	0.07	0.08	−0.03	0.14

*$p < 0.05$ statistical significance.

Table V. Correlations between morphological parameters of the mandible (according to Tallgren [28]) and angular parameters (according to Ricketts [24–26] and McNamara [27]) (columns in the table contain Pearson's correlation coefficient *r*).

	Angular parameters according to Ricketts [24–26] and McNamara [27] method						
Morphological parameters according to Tallgren [28]	N-FC-A	Ans-Xi-Pm	SNA	SNB	ANB	Mandibular angle	BaN/PTGn
Orientation with respect to ML reference line							
md1	0.18	0.08	0.03	−0.01	0.07	−0.33	0.06
md2	0.43*	0.51*	0.01	0.08	−0.14	−0.19	−0.13
md3	0.30	0.53*	0.25	0.28	0.01	−0.12	−0.16
md4	0.23	0.46*	0.25	0.23	0.10	−0.14	−0.23
md5	0.21	0.51*	0.29	0.35	−0.02	−0.03	−0.36
md6	0.26	0.49*	0.27	0.33	−0.03	0.04	−0.37
md7	0.21	0.47*	0.28	0.32	0.02	0.10	−0.37
Sm (B)	0.20	0.43*	0.25	0.36	−0.15	0.14	−0.30
Orientation with respect to MLP reference line							
md5	0.53*	0.34	−0.10	0.03	−0.27	0.27	−0.07
md6	0.29	0.33	−0.02	0.09	−0.21	0.13	−0.26
md7	0.34	0.36	0.03	0.10	−0.27	−0.01	−0.27
Sm (B)	−0.01	0.23	0.01	0.12	−0.20	0.15	−0.34
Others							
Pos-Pg	0.13	0.15	0.21	0.39	−0.27	0.19	−0.06
mds-Sm (B)	0.15	0.33	0.04	0.15	−0.19	0.30	−0.22
Ra	−0.12	−0.08	−0.01	0.00	−0.03	−0.11	−0.07
β angle	−0.07	0.05	0.14	−0.04	0.36	−0.85*	0.09

*$p < 0.05$ statistical significance.

It is assumed that bone dissimilation may be caused by a specific skeletal pattern. A marked mandibular base bend (large β angle, small gonial angle), slight inclination of the mandible to the cranial base, tendency to mandibular prognathism and often small anterior facial height are associated with pronounced resorption of the alveolar part of the mandible [13]. Probably muscular function also affects the morphology of the alveolar part of the mandible. Especially activity of the lower lip and mentalis muscle may increase resorption of the mandibular process. The magnitude of anterior bone reduction decreases with the distance from Pg [13,20,28].

Proper reconstruction of occlusal vertical dimension is of essential importance in prosthetic rehabilitation [29,30–33]. Our findings clearly emphasize the relationship of the occlusal vertical dimension with the height of lateral segments of the body and the alveolar part of the mandible. The correlation observed between the morphological parameters describing the location of the first lower molar (md 3) and linear parameters (according to Ricketts [24–26] and McNamara [27]) characterizing the occlusal vertical dimension seems to indicate a special role of the first molars in the stomatognatic system. The lowest value of md3 among all the md parameters assessed in the study could suggest early bone loss at the sites of teeth 36 and 46, most frequently caused by early loss of these teeth due to caries complications. In some cases, re-inclusion may play a part, leading to local growth inhibition of the alveolar part of the mandible in adolescents, with all the consequences at the stage of toothlessness including setting artificial teeth for dentures [34].

For prosthetic rehabilitation, the use of functionally unstable dentures may have an important effect in modifying the value of the md 3 parameter. Clinically, this kind of prosthetic restoration shows an effect when teeth in lateral regions of the mandible are missing and natural teeth in the opposite dental arch are present. With a decreased prosthetic base (relative to jaws) covered by the lower denture plate, great forces exerted by patients' own dentition lead to resorption. The occlusal surface of natural teeth and the masticatory function ascribed to the molars determine the degree of loading in the distal arch. The teeth which are situated closer to the temporomandibular joint axis exert greater chewing forces [35–37]. It should be mentioned that complete denture wearing in most cases follows the use of partial removable prosthetic restorations, with the consequences in md 3 resulting from settling.

Given the above, the assumptions of Gerber's [34] theory concerning the orientation of teeth 36 and

46 in complete dentures seem justified. The location in the deepest point of the alveolar part of the mandible, through the maximum load transfer to the md 3 region improve the stability of prosthetic restorations. It is unknown, however, whether the suggested procedure does not contribute, via feedback, to resorption enhancement in the md 3 region.

Depression of the alveolar part of the mandible at the level of md 3 may result from natural morphology. Geometrical distribution of the respective parameters md1, md2, md3, md4 and md5 reflects the arch-like shape of the curve of Spee with the radius enlarged at least by the gingivo-occlusal height of the natural dentition. In adolescents, the normal course of the sagittal Spee in the mandible localizes the lowest point at the level of buccal mesial cusps of teeth 36 and 46 [38]. Analogically, in the case of the edentulous alveolar part of the mandible, the deepest point is situated at the level of md 3. Taking advantage of the fact that the curve of Spee runs through the anterior surface of the head of the condyloid process of the mandible and the radius arises from the central point of the orbit, it is feasible to reconstruct the location of the 6th teeth in a newly made prosthetic appliance based on cephalometry. Localization of teeth 36 and 46 in the lower denture, in the region of primary appearance of natural counterparts, is explained by the orthodontic theory of Angle according to which these teeth exhibit stability of the eruption site.

The period of edentulism was found to be negatively correlated with the md5 parameter, which describes the anterior segment of the body of the mandible within its symphysis. It means that, with the progression of the age in complete denture wearers, it is possible to state bone loss not only in the alveolar part of the jaw but in the core of the mandibular symphysis also. Alveolar ridge resorption in this area—as has been written in the introduction—runs conversely–concentrically (centripetal). A decrease in the size of the beta angle, in turn, may be associated with changes in the angle of the mandible. In many cases magnification of the mandibular angle is noted. From a geometric point of view the lower jaw in the lateral profile can be described as a triangle. An increase in the value of one of the three angles results in a decrease of the other. The total value of all angles is always 180°. Re-modeling processes within the mandibular angle may probably affect positive correlation between the edentulous period time and md 1- ML measurement.

The implications between the md 3 parameter and the parameters determining the occlusal vertical dimension of the lower face (G'-Me', N-Me, Ans-Me, Sn'-Me', Ans-Xi-Pm) seem to be of major significance. They indirectly suggest a potential relationship between the radius of the curve of Spee and vertical component of central occlusion. This suggestion creates a new perspective for establishing the vertical component based on tele-X-ray diagnostics [29,39]. Perhaps the orientation of the curve with a specific radius on the X-ray could be helpful in determining the occlusal plane and indirectly other elements of vertical occlusion dimension and occlusion in the newly made dentures.

Directly proportional correlations may also result from definite skeletal patterns. An increase in mandibular inclination to the base of the upper jaw in adolescents leads to compensation of direction of growth [11]. In many cases in teenagers we observe Long face syndrome. These compensatory processes cause elongation of the alveolar part of the mandible and, thus, an increase in the vertical component (increased G'-Me', N-Me). Summing up, individuals with elongated lower face (increased Ans-Me, Ans-Xi-Pm, Sn'-Me') can be expected to have higher values of morphological md parameters in the edentulous period. Moreover, the skeletal type with enhanced inclination and posteriorotation of the mandible with a simultaneous decrease in β angle, correlates with reduced activity of the stomatognatic system muscles [13,33,40]. Low bioelectrical activity suggests lower compression of the stress-bearing area exerted by a denture plate. It is, thus, a prophylactic factor of resorption processes expected to ensure higher values of md parameters at the stage of total tooth loss. Unger et al. [41] as well as Nissan et al. [42] did not reveal any differences in the correlations of various skeletal patterns with resorption degree of the alveolar part and the body of the mandible. However, they noted lower initial values of morphological indices, corresponding to the md in subjects with a small mandibular angle.

The morphology of the alveolar part of the mandible described by the ratio of md 5, md 6 and md 7 parameters to the reference lines ML and MLP is modified by anteroposterior location of the incisors in the lower denture. Resorption increases when the incisive borders show more lingual location compared to natural dentition [41]. Moreover, the enhanced activity of the oral orbicular muscle, mentalis muscle and the activity of the glossal muscles intensify the regressive processes [13].

A relatively constant dimension of the Pos-Pg parameters and Ra excludes correlation attempts in directly or reversely proportional categories. At the same time, due to slight standard deviations that accompany the mean values, Ra and Pos-Pg can be treated as reference standards for edentulous subjects with methodologically defined criterion. Lack of correlation between Ra, Pos-Pg and individual cephalometric variables according to the analysis of Ricketts [24–26] and McNamara [27] suggests a linear relationship of stable monotonicity. This means that, irrespective of changes observed in a cephalometric parameter due to prosthetic rehabilitation (e.g. a change in the occlusal vertical component) or involutional processes, the Ra and Pos-Pg values do not undergo any significant alterations.

A relative stability of the Pos-Pg parameter can be substantiated by classification of alveolar mandible atrophy according to Cawood and Howell [18]. The Pg point is located below the course of the alveolar nerve canal, where the height of the mandibular body remains stable throughout adult life [43]. Due to the lack of bony support for the attachments, mentalis muscle should not exert any effect on modification of the Pos–Pg parameter. Also Ra, i.e. width of the mandibular ramus at its incisure, shows life-long stability [44,45].

Our study confirms the existence of a relationship between the vertical occlusal dimension of centric occlusion and bone morphology of the mandible. To determine the vertical components according to mandibular morphology, further research would be necessary. Cephalometric norms in edentulous should be defined to ensure reliable and comparable results of the prosthetic therapy. It is necessary to identify standards for different skeletal types—long or short face syndrome. Currently it is possible to refer reported results to the reference values of young people with natural dentition. Perhaps the results of subsequent studies allows us to specify a mathematical formula that uniquely will determine clinical procedures including establishing a vertical occlusal dimension.

Conclusion

The current study conducted on edentulous subjects showed a directly proportional correlations between the vertical occlusal dimension of the lower face conditioned by prosthetic rehabilitation and the height of the alveolar part in the lateral regions of the mandible including the location of the first molars. Special attention was given to md 3 region which remained in relation with position of the first lower molar.

Summary

The relationship between facial morphology and the structure of the alveolar part of the mandible in edentulous was studied on lateral radiographs of 25 Caucasian patients.

The study results revealed a lack of correlation between the age of subjects and the morphological parameters of the mandible.

The period of edentulism was found to be negatively correlated with the md5 parameter, which describes the anterior segment of the body of the mandible within its symphysis. It means that, with the progression of the age in complete denture wearers, it is possible to state bone loss not only in the alveolar part of the jaw but in the core of the mandibular symphysis also.

The findings clearly emphasize the relationship of the occlusal vertical dimension with the height of lateral segments of the body and the alveolar part of the mandible. The correlation observed between the morphological parameters describing the location of the first lower molar (md 3) and linear parameters (according to Ricketts [24–26] and McNamara [27]) characterizing the occlusal vertical dimension seems to indicate a special role of the first molars in the stomatognatic system. According to Gerber's [34] theory concerning the orientation of teeth 36 and 46 in complete dentures, the location in the deepest point of the alveolar part of the mandible through the maximum load transfer to the md 3 region improves the stability of prosthetic restorations.

The implications between the md 3 parameter and the parameters determining the occlusal vertical dimension of the lower face (G'-Me', N-Me, Ans-Me, Sn'-Me', Ans-Xi-Pm) appear to be of major significance. They indirectly suggest a potential relationship between the radius of the curve of Spee and vertical component of central occlusion. This suggestion creates a new perspective for establishing the vertical component based on tele-X-ray diagnostics. Perhaps the orientation of a curve with a specific radius on the radiograph could be helpful in determining the occlusal plane and indirectly other elements of vertical occlusion dimension and occlusion in the newly made dentures.

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