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Electronic analysis of mandibular movements during speech depending on the skeletal class

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ABSTRACT
Speech is one of the most important functions of the stomatognathic system. The aim of the study was to assess mandibular movements during speech depending on the skeletal class and the mutual relationship between the incisors. Forty-nine patients without functional disorders of the masticatory organ were examined. In subjects with skeletal class I, the mean length of condylar motion in the sagittal plane was 0.8 mm; in the case of class II, it was – 1.2 mm; and for class III, it was 0.9 mm. There was no statistically significant correlation between the examined parameters of mandibular translation movement during speech with gender or skeletal class. However, the correlations between the maximum mandibular rotation angle and the position of the incisors were statistically significant.
Keywords: phonation; axiograph; condylar movement; skeletal frame; incisors.

INTRODUCTION

The stomatognathic system participates in many important functions, such as chewing, breathing, swallowing, stabilizing body posture, expressing emotions and speaking. Speech is a special human function because it plays an important role in communication [1]. Slavicek, referring to Bühler's theory, lists 4 basic functions of human speech: argumentative, descriptive, signalling and expressive. The examination of the masticatory organ function should also include the analysis of mandibular movements during speech [2]. Many masticatory structures are involved in this communication function. The creation of sounds is possible owing to a particularly specialized activity undertaken by the respiratory system, especially the larynx together with the vocal cords. Speech is also associated with correct mandibular mobility, the cooperation of many muscles, including the suprahyoid and infrahyoid muscles, the pharynx and the soft palate, and the appropriate positioning of the tongue in relation to the front teeth, as well as the positioning of the cheeks and lips [3]. The position of the upper and lower incisors is important for the pronunciation of individual consonants [4]. The relationship between the upper and lower teeth, the vertical and horizontal overlap, as well as the inclination of their long axes, affect the creation of an appropriate space for the tongue. Incisors can be considered in this context as a functional group of teeth, with a characteristic, individually variable inclination. In relation to speech, their palatal surface is of particular functional importance.

The issues of spatial registration and analysis of mandibular movements have always been of interest to dentists. The continuous development of new technologies has resulted in a wide range of various measurement methods and systems for recording mandibular movements [5]. It is interesting to study mandibular mobility not only during selected mandibular movements such as protrusion-retrusion, opening and closing, and lateral movements but also during functions like chewing, swallowing and speaking [6, 7]. The movements of the mandible during speech have been little studied and scientific reports do not indicate a clear relationship between the parameters of these movements and the skeletal frames of the human skull.

The aim of the study was an axiographic analysis of mandibular movements during speech, depending on the skeletal class and the relationship between the upper and lower incisors.

MATERIALS AND METHODS

Forty-nine subjects were qualified for the study, including 32 women and 17 men aged 23–32 (the mean age was 24). All were generally healthy, with full dentition and without functional disorders of the masticatory organ.

Condylar movements were recorded using computerized axiography (Cadiax Diagnostic Gamma Co., Austria). The examination procedure was as described in [8, 9]. A double face bow was used; the upper one was attached to the patient's head with an elastic strap and the lower one was attached to the lower teeth with a functional paraocclusal clutch, composite material and tissue glue. A paraocclusal clutch was individually adapted to the labial and buccal surfaces of the lower teeth. Electronic flags were sagittally mounted on the upper bow, on which mandibular movements were recorded by means of styli rigidly mounted on the lower bow. The study was started by determining the individual hinge axis of the condyles and the reference position, which is a reproducible, retral border position of the condyles [2]. The system was equipped with 2 pins that recorded condylar rotation and translation movements. The device was connected to a computer to record mandibular movements.

The subjects were instructed to count 60–69 in Polish, because this sequence of numbers contains many sibilants and when pronouncing words containing the letter "s", the mandible is most protruded [3, 4]. Mandibular movements during speech were analysed on the basis of graphs (Fig. 1).

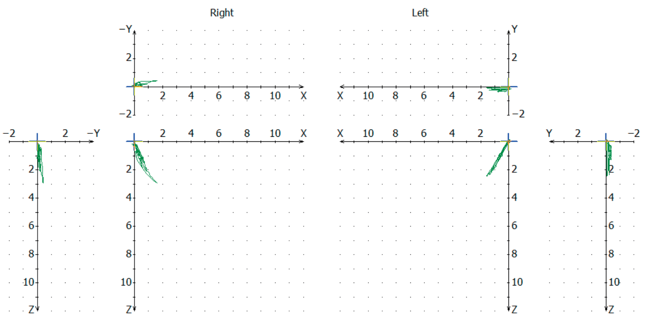

FIGURE 1. Graph of mandibular movements during speech, an example of an examination result of a skeletal class I patient

The distance from the end to the starting point of movement was measured in 3 planes: sagittal, horizontal and frontal. The value of the Gamma rotation angle of the mandible on the Y-axis was also read from the graph, providing the maximum value (Fig. 2).

The analysis ignored the exceptionally high values of the Gamma rotation angle, which occurred during inhalation. During the axiographic examination, the individual hinge axis of the mandible and the reference position were determined, and then the patients were instructed to say a given sequence of numbers aloud.

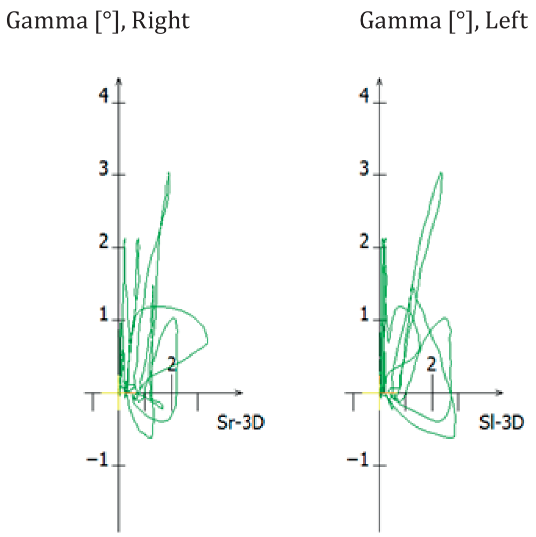

FIGURE 2. Graph of Gamma mandibular rotation axis during speech, an example of an examination result of a skeletal class I patient

The range and symmetry of the movements of the condylar processes of the mandible were analysed on the basis of graphs obtained during the axiographic examination. The ranges of movements of the mandibular head on the right and left sides were assessed based on graphs in the sagittal (dx), horizontal (dy) and coronal (dz) directions, as well as its Gamma rotation angle. The ranges of mandibular movements in all directions were mathematically calculated based on the coordinates of the beginning and end of the movement read from the graph: $dx = x2 – x1$, $dy = y2 – y1$, $dz = z2 – z1$. The spatial displacement was calculated using the following formula: $dxyz = \sqrt{(x2 – x1)^2 + (y2 – y1)^2 + (z2 – z1)^2}$, where x1, y1, z1 were the initial coordinates and x2, y2, z2 were the final coordinates of the mandibular movements, respectively. The Gamma rotation angle was read from the plot on the Y-axis (maximum value).

Cephalometric analysis of teleroentgenograms according to Segner and Hassund's method was also performed using the Ortobajt 7 software.

Statistical analysis

Parameter values were compared between the groups using the Kruskal–Wallis and Mann–Whitney tests. The pairwise Wilcoxon test was used to compare the results of measurements on the right and left sides. The correlations between parameters were analysed by calculating the Spearman's rank correlation coefficient. The threshold of statistical significance was $p < 0.05$. Calculations were made using the Statistica 10 software.

The approval of the Bioethics Committee of Pomeranian Medical University in Szczecin No. KB-0012/12/13 of 21-01-2013 was obtained.

RESULTS

The ranges of mandibular movements during speech in women and men are presented in Table 1. The mean sagittal motion length was 1.7 mm in females and 1.6 mm in males. Differences based on gender were not statistically significant in any of the

TABLE 1. Range of mandibular movements during speech depending on gender

	Females (n = 32)			Males (n = 17)			
Direction	mean	range	SD	mean	range	SD	p
dx	1.03	0.01–3.71	0.75	0.89	0.08–2.81	0.77	>0.05
dy	0.18	0.00–0.74	0.16	0.21	0.01–0.63	0.16	>0.05
dz	1.31	0.02–3.39	0.85	1.33	0.10–3.29	0.97	>0.05
dxyz	1.71	0.00–5.03	1.10	1.58	0.22–3.90	1.21	>0.05
Gamma angle	3.00	0.03–8.50	1.87	2.70	0.53–4.01	0.93	>0.05

n – number of participants; SD – standard deviation; p – significance level; dx – sagittal direction; dy – horizontal direction; dz – coronal direction; dxyz – spatial displacement

TABLE 2. Range of mandibular movements during speech depending on the skeletal class

	Skeletal class I (n = 25)			Skeletal class II (n = 17)			Skeletal class III (n = 7)			
Direction	mean	range	SD	mean	range	SD	mean	range	SD	p
dx	0.81	0.10–2.01	0.52	1.20	0.00–3.73	0.93	0.90	0.10–2.22	0.85	>0.05
dy	0.22	0.00–0.73	0.18	0.22	0.00–0.41	0.14	0.10	0.01–0.24	0.07	>0.05
dz	1.09	0.10–3.28	0.86	1.60	0.00–3.38	0.87	1.13	0.10–2.30	0.92	>0.05
dxyz	1.42	0.10–3.91	0.99	2.12	0.00–5.02	1.22	1.52	0.21–3.23	1.22	>0.05
Gamma angle	2.61	0.40–5.32	1.25	3.01	0.00–5.74	1.75	3.49	1.58 –8.50	2.33	>0.05

n – number of participants; SD – standard deviation; p – significance level; dx – sagittal direction; dy – horizontal direction; dz – coronal direction; dxyz – spatial displacement

studied directions of condylar displacement. The symmetry of mandibular movements on the right and left sides was also analysed, and no statistically significant differences were found, which proves that the symmetry of movements was maintained. The mean condylar rotation angle was 3.0° in women and 2.7° in men; gender differences were not statistically significant.

The cephalometric analysis according to Segner and Hassund's method showed that in the study group there were 25 subjects with skeletal class I, 17 with skeletal class II, and 7 with skeletal class III.

Table 2 presents the data on the range of condylar motion during phonation in individual skeletal classes. In subjects with skeletal class I, the mean length of condylar motion in the sagittal plane was 0.8 mm; in the case of class II it was the longest – 1.2 mm; whereas for class III, similarly to class I, it was 0.9 mm. Differences in the range of mandibular movements in all studied directions depending on the skeletal class were not statistically significant in the study group. The Gamma rotation angle of the condyle was 2.6° in skeletal class I patients, 3.0° in class II patients, and 3.5° in class III patients. Differences in the range of these movements in the sagittal, frontal and horizontal planes did not differ statistically significantly between the skeletal classes of the examined subjects.

Table 3 presents data on the relationship between the upper and lower incisors, taking into account the overbite, overjet and angles between the upper incisors and the NA line and the lower incisors and the NB line.

TABLE 3. Relationship between the upper and lower incisors

Parameter	Minimum	Maximum	Mean	Standard deviation
Overbite	−8.60	32.00	6.57	8.35
Overjet	0.60	21.90	5.30	5.57
+1:NA angle	3.00	53.32	23.68	9.22
−1:NB angle	12.24	40.40	26.44	7.11

A statistically significant correlation was found between the vertical overbite of the incisors and the angle of inclination of the incisors as well as the Gamma rotation angle of the individual kinematic axis of the mandible during speech – Table 4. The correlation between the mandibular rotation and horizontal mandibular overjet was not statistically significant.

TABLE 4. Correlation between the Gamma angle of rotation of the mandibular hinge axis and the position of the incisors

Parameter	Spearman's rho	p
Overbite	0.395459	<0.05
Overjet	0.132721	>0.05
+1:NA angle	0.329507	<0.05
−1:NB angle	−0.29808	<0.05

p – significance level

DISCUSSION

The stomatognathic system participates in one of the most important aspects of human life, which is verbal expression. Muscle activity during speech is not as great as during chewing. Mandibular movements take place in a smaller range, but they are nevertheless very complex, sophisticated movements which involve many muscles. As shown in the conducted research, the initial condylar movement taking place in the lower portion of the temporomandibular joint is influenced by the relationship between the incisors, their overbite and the angle of inclination of the long axis. It is therefore necessary to emphasize the need for further research on the factors influencing mandibular movements during speech, especially in patients with masticatory system dysfunctions. The results of the study showed that the forward mandibular movement during phonation was on average about 1 mm. In people with skeletal class II, this movement was longer due to the posterior position of the mandible, and this group of patients should be expanded and investigated more thoroughly.

In this study, a group of patients without functional disorders was intentionally selected and no differences in the symmetry of movements of both mandibular condyles on the right and left sides were found. The research is preliminary and will be continued in patients with functional disorders, e.g. lateral displacement of the mandible, as well as in skeletal class II patients. Akimoto et al. note that in skeletal class II patients, the craniomandibular system must compensate for this function by moving the mandible forward more, whereas in skeletal class III patients, mandibular movements during speech take place at a shorter distance from the reference position. Overcompensation may result in retrodiscal tissue strain and muscle overload, which clinically may manifest as fatigue during speaking [3]. Studies by other authors indicate that the maximum range of mandibular movements depends on skull morphology. The comparison of the length of the axiographic curves during protrusion showed significantly higher values in the class II group than in the class I group and higher in the class I group than in the class III group. However, during speech, mandibular movements occur to a much smaller extent, mainly in the anteroposterior direction with a slight lateral displacement and vertical movement, and the range of these movements is not dependent on skeletal classes [10]. The correctness of speech production also depends on the position of the incisors. The relationship between the incisors, including their vertical overlap and the angle of inclination, has a significant impact on the mandibular rotation angle. In patients with deep incisor overlapping, the mandibular axis rotation angle must be sufficiently large to enable the speech function to be performed. The influence of the relationship between the incisors on the speech function has also been confirmed by studies by Peraire et al. [11]. Many authors emphasize the necessity of examining phonation, especially in patients with functional disorders of the masticatory system. Three-dimensional clinical studies of mandibular movements during speech with the use of specialized devices recording these movements may provide more precise answers to questions about mandibular function and occlusal dysfunction [12, 13].

Another aspect that needs to be included in the phonation analysis is the assessment of muscle activity involved in the correct pronunciation of syllables. Aberrant tongue function, its low resting position as well as swallowing malfunction may cause both functional and morphological changes in the position of the mandible and, consequently, speech defects. Similarly, the activity of the orbicularis oris muscle and the presence of incompetent lips can be both the effect and the cause of phonation disorders, but it can also be associated with the occurrence of malocclusion, such as backbite with incisor protrusion – class II/1 malocclusion [14].

CONCLUSION

In the study group, the range of mandibular movements during speech was the greatest in skeletal class II patients, but no statistically significant differences were found depending on the skeletal frame and gender. However, statistically significant correlations were found between the angle of rotation of the individual kinematic axis of the mandible and selected occlusal parameters, especially the overbite of the incisors and the angle of their inclination. The obtained results indicate a greater impact of dento-occlusal parameters than skeletal relations on mandibular movements during speech in the study group.

REFERENCES

1. American Academy of Prosthodontics. The glossary of prosthodontic terms: ninth edition. J Prosthet Dent 2017;117(5S):e1-105. doi: 10.1016/j.prosdent.2016.12.001.
2. Slavicek R. The Masticatory organ-function and dysfunction. Klosterneuburg: Gamma Medizinisch-wissenschaftliche Fortbildungs-AG; 2002. p. 219-302.
3. Akimoto S, Kubota M, Sasaguri K, Quismundo CP, Slavicek R, Sato S. Condylar movement in different skeletal frames during phonation assessed by condylography. Stomatologie 2008;105:7-12.
4. Burnett CA. Mandibular incisor position for English consonant sounds. Int J Prosthodont 1999;12(3):263-71.
5. Postić S, Teodosijević M. Elektrognatografija i mogucnosti njene primene u stomatologiji. Stomatol Glas Srb 1990;37(1):63-70.
6. de Serrano PO, Faot F, Del Bel Cury AA, Rodrigues Garcia RC. Effect of dental wear, stabilization appliance and anterior tooth reconstruction on mandibular movements during speech. Braz Dent J 2008;19(2):151-8. doi: 10.1590/s0103-64402008000200012.
7. Peraire Ardevol M, Salsench Cabre J, Gascon Mayordomo F, Torrent Collado J. Determination of kinesiographic parameters in phonation. Rev Actual Odontoestomatol Esp 1990;50(396):35-8.
8. Piehslinger E, Čelar AG, Celar RM, Slavicek R. Computerized axiography: principles and methods. Cranio 1991;9(4):344-55.
9. Piehslinger E, Čelar A, Futter K, Slavicek R. Orthopedic jaw movement observations. Part I: Determination and analysis of the length of protrusion. Cranio 1993;11(2):113-7. doi: 10.1080/08869634.1993.11677952.
10. Zimmer B, Jäger A, Kubein-Meesenburg D. Comparison of 'normal' TMJ--function in Class I, II, and III individuals. Eur J Orthod 1991;13(1):27-34.
11. Peraire M, Salsench J, Torrent J, Nogueras J, Samso J. Study of mandibular movements during speech. Cranio 1990;8(4):324-31. doi: 10.1080/08869634.1990.11678333.
12. George JP. Using the Kinesiograph to measure mandibular movements during speech: a pilot study. J Prosthet Dent 1983;49(2):263-70. doi: 10.1016/0022-3913(83)90513-9.
13. Bianchini EMG, de Andrade CRF. A model of mandibular movements during speech: normative pilot study for the Brazilian Portuguese language. Cranio 2006;24(3):197-206. doi: 10.1179/crn.2006.032.
14. Naqvi Y, Gupta V. Functional voice disorders. Treasure Island (FL): StatPearls Publishing; 2023.