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Registration and Measurement of Opening and Closing Jaw Movements and Rotational Mandibular Capacity by Using the Method of Electronic Axiography

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A B S T R A C T

The aim of this study was to register and measure lower jaw movements, to analyse the measured length of opening and closing movements and to analyse the rotational mandibular capacity during the maximal opening of the mouth in the position of centric relation. Our objective was to determine the average values for each mandible and temporomandibular joint movement, as well as to determine the accuracy of electronic axiography, while diagnosing temporomandibular joint disorders. A statistical analysis was performed in order to evaluate whether significant differences between the length of the measured movements in asymptomatic and symptomatic subjects could be found. A symptomatic group consisted of 51 subjects with temporomandibular disorders. A control group consisted of 43 subjects without signs and symptoms of temporomandibular joint disorders. Each subject was registered by the GAMMA CADIAX system for registration of position and movement of the lower jaw, which consists of a conventional SAM axiograph, an electronic device for drawing curves by means of a computer. No significant differences were found between the groups of subjects for the measured variables. The results of the length of the mandibular and condyle movements, along with the rotational capacity of the mandible are important, in spite of unreliable indicators of temporomandibular joint function. Description analysis of a graphic recording of mandibular and TMJ movement remains an accurate evaluation method for the determination of TMJ dysfunction.

Key words: *jaw movements, electronic axiography*

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Introduction

A temporomandibular joint disorder consists of a wide spectrum of clinical problems in the temporomandibular joint and the muscles in the orofacial region. These disorders are primarily characterised with pain, tinnitus, and irregular or restricted joint function. Temporomandibular joint disorders also include a subgroup of musculoskeletal and rheumatoid disorders, which represent the main causes of pain in the orofacial region and are not connected with teeth. It is of utmost importance for dentists to be aware of their individual responsibility when diagnosing and treating temporomandibular disorders. A balanced function of the stomatognathic system is guaranteed by the continuous mechanism of feedback and adaptation capacity. The involved tissues are thus protected against possible damage. The disorders of the stomatognathic system are disorders which are the consequences of causative factors along with consecutive tissue changes. Various contributing factors (i.e. occlusal disorders, parafunction, dysfunction, trauma) on the one hand and progressive adaptation capacity, on the other hand, to a physiological state of balance, which is characterised by a detailed dental history with no problems. When the accumulation of such effects in time exceeds the individual possibilities of system adaptation, or the possibility to adapt is generally decreased, the system is considered out of balance. Such a state is called decompensation or regressive adaptation and is characterised by more or less pronounced clinical and subjective symptoms. The organism is often capable of adaptation by use of compensatory mechanisms and the tolerance limit varies with indivbiduals. However, the system functions in a state of labile balance. Due to a loss of tolerance or increase in the functional disorder, frequently after prosthetic appliances are made, the organism cannot compensate the new state and therefore a partial or total system breakdown occurs. Literature data report various underlying causes which lead to the dysfunction of the stomatognathic system such as trauma, anomalies in the teeth position, parafunction habits, the condition of dysfunctional occlusion, gender and psychological factors[1–5]. Teeth loss, especially of the supporting zone, leads to the movement, mesialisation and rotation of the surrounding teeth, elongation of the antagonists and consequently to the occlusal dysfunction. Clinical and experimental studies confirm that occlusal interference leads to the muscle hyperactivity which results in the teeth grinding and clenching. These parafunction habits result in a muscle and temporomandibular joint disorders and are known as: myopathy, arthropathy and myoarthropathy[6].

The most frequent symptoms of temporomandibular joint disorders are tinnitus, muscle and joint sensitivity, pain, restricted or deviated mandibular movements, pain in the facial region together with headache[7]. True dysfunction can only be detected by means of a precise functional analysis. Apart from the subjective symptoms, objective symptoms of occlusal disorder of the stomatognathic system can be confirmed. Painful myopathy often occurs after quite unnoticed problems in the temporomandibular joint which are sometimes accompanied by teeth grinding and clenching. Occasionally when the dysfunction is prominent it can manifest itself as trigeminal neuralgy[8,9]. A higher incidence of these disorders, which are often a consequence of the psychological stress of modern life prompts us to recognise and treat them promptly and knowledgeably[10].

Dental functional diagnostics shows the functional state of the masticatory system. In patients with temporomandibular joint disorders it consists of correct diagnosis which is of utmost importance for every prosthodontic and orthodontic patient before the treatment[11]. Instrumental analysis of lower jaw movements is the dynamic registration of these movements as well as their diagnostic interpretation. The cornerstone of modern thinking includes the method as a source of important additional data, which are added to a detailed dental history and manual functional analysis. Registration of condyle movements helps to compare physiological and pathological conditions, and by use of these results an individual articulator can be programmed. Instrumental functional analysis can provide data on individual values in patients with temporomandibular joint disorders (curve and angle of condyle path, Bennets angle, mediotrusional and latertrusional path) along with the registration of path movement in the active and conducted movements of the lower jaw as well as on changes in the condyle position caused by occlusal contributors. Every movement of the lower jaw can be described as rotation of an imaginary stationary or transverse hingeaxis in the temporomandibular region. This hingeaxis is a constant parameter of every system for registration of movements and position of the lower jaw[12]. If an imaginary hingeaxis of the mandible could be determined, composed translation movements of the mandible could be repeated as a clear movement of the hingeaxis. By use of intercondylar distance (the distance between the right and left condyle) registered movement of the hingeaxis becomes the true path. This is the principle of the function of every system for registration of movements using hingeaxis. Depending on diagnostic criteria, almost all procedures which can register and document lower jaw movements could be used. Apart from simple data sampling, electronic and computed devices for recording lower jaw movements have an advantage, because extraarticular measuring data could be calculated by use of intercondylar distance and therefore could be projected as a condyle translation. Direct comparison of the condyle paths has a particular diagnostic significance, which could be performed with or without teeth contact. Paraocclusal application of the recording device represents that comparison[13,14].

Occlusal position and dynamic movements of the lower jaw could be registered by use of paraocclusal registration. If the movement paths conducted with teeth and those conducted without teeth are the same (i.e. protrusion or mesiotrusion) occlusion has no clinical significance for the temporomandibular joint. Therefore, we can conclude that the occlusion and joint are balanced. Disorders in jaw movement with changes in the condyle position caused by occlusal factors are easily observed by means of instrumental functional analysis when compared with manual analysis. The aim of this study was to register and measure lower jaw movements, to analyse the measured length of opening and closing movements and to analyse rotational mandibular capacity during the maximal opening of the mouth in the position of centric relation. Our objective was to determine average values for each mandible and temporomandibular joint movement, as well as to determine the accuracy of electronic axiography, while diagnosing temporomandibular joint disorders. A statistical analysis was performed in order to evaluate whether significant differences between the length of the measured movements in asymptomatic and symptomatic subjects could be found.

Material and Methods

A symptomatic group consisted of 51 subjects with temporomandibular disorders. A control group consisted of 43 subjects without signs and symptoms of temporomandibular joint disorders. The distribution of the two groups according to gender is presented in Table 1. In the symptomatic group of subjects, the signs and symptoms of temporomandibular disorders were crepitation, bruxism, sensitivity, pain in the temporomandibular joint and muscles, as well as pain and sensitivity in the region surround and anterior to the ear, along with difficulties in opening the mouth. Out of the total number of subjects, 63 were women (67%), age range 15–73 years, mean 38, and 31 men (33%), the age range 19–63 years, mean 35. The mean age of symptomatic subjects was 37 years, age range 15–73, and of asymptomatic subjects 37 years, age range 21–69. Each subject was registered by the GAMMA CADIAX system for the registration of position and movement of the lower jaw, which consists of a conventional SAM axiograph, an electronic device for drawing of curves by means of a computer. Before instrumental examination each subject was informed about the procedure and the aim of the study and the pattern of movements as well as with every procedure during the registration. The procedure is to exercis before the facebow is adapted. All the performed measurements were put in the database where the rows represent all the measurements of the individual subject for the period and the columns consist of data concerning the measured movements (distances, angles). Over the time step measurement was 0.009 seconds, for 4.5 seconds of the duration of the experiment. Spatial coordinates of every movement with regard to the reference system of the instruments (x, y, z) were used for a three-dimensional movement report as simplified analysis of individual symptomatic and asymptomatic cases. Statistical analysis was performed using variables which showed the maximal lengths of movements and the rotational angle of the mandible whilst maximal opening and age of the subjects according to the gender and type of diagnosis, i.e. symptomatic or asymptomatic group was registered. All these variables are presented in Table 2. Possible structural differences

TABLE 1
NUMBER AND PERCENTAGE OF SUBJECTS ACCORDING TO GENDER AND THE PRESENCE OF SYMPTOMS OF TEMPOROMANDIBULAR DYSFUNCTION

Gender	N	Asymptomatic		Symptomatic	
		N	%	N	%
Male	31	11	35.5	20	64.5
Female	63	40	63.5	23	36.5
Total	94	51	54.3	43	45.7

TABLE 2
EXAMINED VARIABLES

Code	Appellation	Category
Age	Years of life	
Gender	Gender of subject	1 Male 2 Female
Symptom	Presence of symptoms of temporomandibular dysfunctions	1 Asymptomatic 2 Symptomatic
SR3D-o	Maximal opening movement in the right joint (mm)	
SL3D-o	Maximal opening movement in the left joint (mm)	
GAMA-o	Rotational angle of the mandible during maximal opening (°)	

of the lengths of maximal opening of the mandible together with its rotational angle according to the age and presence or absence of symptoms of craniomandibular dysfunctions are tested with a model of bifactorial variance analysis, i.e. hypothesis of non-existence of differences between their average values in subspecimens which are combined with these factors. As the distribution of the investigated variables was not normal in all cases, the results of testing by means of parametric methods were also tested with appropriate non-parametric tests (Kruskal-Wallis test for non-parametric data). Normality test was performed using Kolmogorov and Smirnov test.

Results

Table 3 shows maximal values of the opening length in the right joint for asymptomatic and symptomatic groups of male and female participants (SR3D-o). In the asymptomatic group, values of the opening length ranged from 4.27 to 25.94 mm, mean 14.63 mm. For the symptomatic group, maximal opening length values ranged from 0.89 to 24.74 mm, mean 14.45 mm. Table 4 shows the values for the opening movement of the left joint (SLL3D-o). In the asymptomatic group the values for the opening movement in the left joint ranged from 3.09 to 24.66 mm, mean 15.65 mm. v The values for the symptomatic group ranged from 3.59 to

TABLE 3
MAXIMAL OPENING MOVEMENT IN THE RIGHT JOINT (MM) ACCORDING TO GENDER AND SYMPTOM

Gender/symptom	N	X	SD	Min.	Max.
Male/asymptomatic	20	14.877	4.100	8.26	22.46
Male/symptomatic	10	15.507	3.243	9.57	19.13
Female/asymptomatic	23	14.414	5.044	4.27	25.94
Female/symptomatic	40	14.179	5.586	0.89	24.74
Male	30	15.087	3.790	8.26	22.46
Female	63	14.265	5.354	0.89	25.94
Asymptomatic	43	14.629	4.581	4.27	25.94
Symptomatic	50	14.445	5.201	0.89	24.74
Total	93	14.530	4.899	0.89	25.94

TABLE 4
ANALYSIS OF MAXIMAL OPENING MOVEMENT IN THE RIGHT JOINT (MM) BY A TWO-FACTORIAL MODEL OF ANALYSIS OF VARIANCE

Source of variation	Sum of squared deviation	df	Corrected variance	Test statistics	p
Major effect:	14.824	2	7.412	0.301	0.741
Gender	14.683	1	14.683	0.597	0.442
Symptom	0.714	1	0.714	0.029	0.865
Interaction:					
Gender x Symptom	3.424	1	3.424	0.139	0.710
Explained	17.191	3	5.730	0.233	0.873
Random error	2190.434	89	24.612		
Total	2207.626	92	23.996		

TABLE 5
ROTATIONAL ANGLE OF THE MANDIBLE DURING MAXIMAL OPENING (°) ACCORDING TO GENDER AND SYMPTOM

Gender/symptom	N	X	SD	Min.	Max.
Male/asymptomatic	20	25.746	7.359	12.37	35.84
Male/symptomatic	10	26.437	4.620	21.71	37.02
Female/asymptomatic	23	26.648	6.074	15.30	35.28
Female/symptomatic	40	27.225	7.985	1.49	39.43
Male	30	25.976	6.497	12.37	37.02
Female	63	27.014	7.299	1.49	39.43
Asymptomatic	43	26.228	6.636	12.37	35.84
Symptomatic	50	27.068	7.401	1.49	39.43
Total	93	26.679	7.032	1.49	39.43

25.18 mm, mean 16.14 mm. Mean value of the maximal lenght of the opening movement was 16.14 mm. Mean value of the maximal length of the opening movement in male subjects for the right joint was 15.09 mm, and for the left joint 16.5 mm. In female subjects, values were 14.26 mm, and 15.63 mm. No significant differences were found between the given values of maximal lenghts of the opening movements in the left and right temporomandibular joint between males and females as well as between the groups of asymptomatic and symptomatic subjects. The results of the bifactorial variance analysis in Table 5 shows the values of the rotational angle for the mandible measured during maximal opening of the mouth (GAMA-o). In the asymptomatic group the values of the rotational mandibular angle were 12.37–35.84°, mean 26.29°. The values for the symptomatic group were 1.49–39.43°, mean 27.07°. The mean value for the rotational angle of the mandible in males was 25.98° and in females 27.01°. No significant diferences were found between the values of the rotational mandibular angle in males and in females nor between the groups of symptomatic and asymptomatic subjects.

Discussion

Various mechanical and electronic devices have been used for the investigation of jaw and condyle movements. However, the diagnostic accuracy of the investigated electronic devices has not yet been completely evaluated. The disorders of temporomandibular joint biomechanics especially increased translation is suggested as a predisposing factor which contributes to the development of temporomandibular joint disorders. Cooper[15] highlights the importance of electronic devices which register and measure biological phenomena, their use as a part of critical analysis provides treatment efficacy. On the basis of scientific data the American Dental Association reported that various appliances which are helpful while diagnosing temporomandibular joint disorders should not be used alone, although they are very sensitive and specific[16,17] compared the clinical examination, the functional examination, the magnetic resonance and axiography while diagnosing temporomandibular joint disorders. The level of condyle movement measured by use of sonography and axiography was significantly equal for opening and protrusion movement, whereas no statistical significance for lateral movements was found. Theusner et al.[18] investigated threedimensional condyle movements using electronic axiography in 49 symptomatic and asymptomatic participants. No differences in the registered movements between symptomatic and asymptomatic subjects were found and the authors concluded that the relationship between condyle registration movement and symptoms of temporomandibular disorder could not be established. Gsellmann et al.[19] examined the movement length of the lower jaw by means of electronic axiography. Kenyworth et al.[20] evaluated possible differences between the path of the temporomandibular joint movements in symptomatic adult subjects, when compared to the asymptomatic adult subjects. Their results revealed that in 63% of asymptomatic and in 100% of symptomatic subjects condyle movements were asymmetric. Although asymmetric condyle movements were present in a large number of symptomatic subjects, the path of condyle movement could not alone represent effective diagnostic criteria when diagnosing temporomandibular dysfunction. However, the registration of saggital condylar movements indicates irregularity of the temporomandibular joint. Osawa and Tanne[21] measured the saggital path of condyle movements by means of axiography and compared them with magnetic resonance findings in subjects with temporomandibular disorders. The authors concluded that axiography alone is not an accurate method while diagnosing temporomandibular joint disorders, especially when temporomandibular joints are chronically changed and/or adapted internally.

Lewis, Buschang and Throckmorton[22] evaluated the differences in maximal opening and closing movement of the jaws according to the gender of subjects. The movements were registered with an optoelectrical device in asymptomatic subjects. Their results showed significant differences in maximal condyle translation between opening and closing movements. In male participants maximal condyle translation ranged from 15.4 mm to 17.6 mm, whereas in female participants it ranged from 12.4 mm to 12.7 mm.

Piehslinger et al.[23] used computed tomography to measure opening movements in 86 asymptomatic and symptomatic subjects. Terminal hinge axis movement together with rotational movement was measured while subjects had maximal opening of the jaws.

The values of the rotation angle of the mandible measured in our study were in agreement with the results of Piehslinger et al.[23]. We can conclude that electronic axiography is an accurate method for the analysis of rotational mandibular capacity. A comparison of our results and those of other authors suggests that electrical axiography is a valuable and practical method for the evaluation of mandibular and temporomandibular joint movements which provides objective criteria for the diagnosis of the TMJ disorders.

No significant differences were found between the groups of subjects for the measured variables which indicates that linear measurement alone is inadequate for an accurate evaluation of the temporomandibular joint function. Therefore, three-dimensional graphic descriptive analysis of mandible and temporomandibular movement should be used.

Conclusion

1. The results of the length of the mandibular and condyle movements, along with the rotational capacity of the mandible are unreliable indicators of the temporomandibular joint function.

2. Description analysis of a graphic recording of mandibular and TMJ movement remains a precise evaluation method for the determination of TMJ dysfunction.

3. The results of this study indicate the need and eligibility of electonic axiography as a valuable clinical tool in diagnosing TMJ disorders.

Electrical axiography is an essential diagnostic method when diagnosing temporomandibular joint disorders and together with clinical functional analysis, electromyography and magnetic resonance imaging provides a successful tool in the diagnosing and treatment of TMJ disorders.

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BILJEŽENJE I MJERENJE KRETNJE OTVARANJA I ROTACIJSKOG KAPACITETA MANDIBULE METODOM ELEKTRONIČKE AKSIOGRAFIJE

SAŽETAK

Svrha istraživanja bila je bilježenje i mjerenje kretnji donje čeljusti, analiza izmjerenih duljina kretnji otvaranja i zatvaranja i analiza rotacijskog kapaciteta mandibule tijekom maksimalnog otvaranja usta u položaju centrične relacije. Naš cilj bio je odraditi srednje vrijednosti za svaku kretnju mandibule i čeljusnog zgloba, kao i odrediti točnost elektroničke aksiografije u dijagnostici temporomandibularnih poremećaja. Statistička analiza provedena je u svrhu procjene značajnosti razlika između duživa izmjerenih kretnji u asimptomatskih i simptomatskih ispitanika. Simptomatsku skupinu ispitanika činio je 51 ispitanik s temporomandibularnim poremećajem. Kontrolnu skupinu činilo je 43 ispitanika bez znakova i simptoma temporomandibularnih poremećaja. Svaki ispitanik snimljen je GAMMA CADIAX sustavom za bilježenje položaja i kretnji donje čeljusti, koji se sastoji od SAM aksiografa, elektroničke naprave za ucrtavanje krivulja i računala. Nisu pronađene statistički značajne razlike između grupa ispitnika za mjerene varijable. Rezultati mjerenja dužina kretnji mandibule i kondila kao i rotacijski kapacitet mandibule su značajan ali ne i pouzdan pokazatelj za funkciju temporomandibularnog zgloba. Deskriptivna analiza grafičkih zapisa kretnji mandibule i čeljusnog zgloba ostaje metoda precizne procjene u dijagnostici teporomandibularnih poremećaja.

Ključne riječi: kretnje mandibule, elektronička aksiografija