Stomatologija, Baltic Dental and Maxillofacial Journal, 9:47-55, 2007

Reliability of ARCUSdigma (KaVo®) in diagnosing temporomandibular joint pathology

Giedre Kobs, Asta Didziulyte, Robertas Kirlys, Mindaugas Stacevicius

SUMMARY

Objectives: to assess the sensitivity and specificity of ARCUSdigma in diagnosing temporomandibular joint (TMJ) pathology (TMD).

Methods. 102 TMJs were exmined with ARCUSdigma and "Cadiax Diagnostic" electronic axiography system. Free opening, free protrusion and mediotrusion were recorded with both devices. Guided opening and guided protrusion were examined with "Cadiax Diagnostic". Using free opening and free protrusion diagnosis was established.

Results. Sensitivity of ARCUSdigma was found to be 84,21% and 92,86% for the right and left TMJ respectively. Specificity – 93,75% and 95,65% for the right and left TMJ. The 95% confidence interval for sensitivity and specificity was calculated.

Conclusions. Within the limitations of this study, ARCUSdigma appeared to be a valuable supplement to clinical findings in diagnosing TMDs.

Key words: temporomandibular joint disorders; axiography; sensitivity; specificity.

INTRODUCTION

Internal derangement of the temporomandibular joint (TMJ) has been defined as an abnormal positional relationship of the disc relative to the mandibular condyle, fossa and/or articular eminence, and is a major cause of jaw pain, clicking and/or crepitation as well as limitation of opening [1]. Systematic examination of TMJ pathology is of utmost importance [2] and the primary goal is to determine the status of the stomatognathic system in the most non-invasive way possible, then to document the situation and plan a therapy, appropriate to the findings.

The increasingly progressive development of medical diagnostic processes has opened new possibilities in the compilation of findings for mandibular disorders.

Magnetic-resonance-tomography (MRT) provides a non-invasive procedure for imaging both the osseous- and soft-tissue structures with a high degree of resolution [3, 4]. Although MRT cannot be considered a routine procedure, due to cost considerations, it is still currently regarded as the best possible diagnostic standard [5, 6, 7, 8].

Diverse instrumental registration techniques of TMJ, based on electro-mechanic, opto-electronic, ultrasound and magnetic principles also exist. According to Meyer [9, 10], there are remote, near-TMJ and TMJ-oriented methods to evaluate lower jaw movements.

Computerized axiography is a noninvasive diagnostic method, wich enables to record jaw movements in three dimensions. After localizing the geometric hinge axis, it is possible to record movements free from distortion, wich are combined of rotation and translation. However, despite refinements and expanded possibilities for registration, the actual significance of instrumental functional analysis in mandibular joint diagnostics is still not conclusively clear. The possibilities for error involved in extraoral registration of functional movements have been discussed elsewhere [10].

Electronic axiograph "Cadiax Diagnostic", which was considered as a reference method in this study, utilizes exactly determined hinge axis - orbital reference plane [11]. ARCUSdigma is a near-TMJ working ultrasonic diagnostic device, that was put on the market 3 years ago. ARCUSdigma is technically sim-

**Institute of Dentistry, Faculty of Medicine, Vilnius University, Lithuania*

Giedre Kobs – DDS, PhD*
Asta Didziulyte – clinical intern*
Robertas Kirlys – clinical intern*
Mindaugas Stacevicius – student*

Address correspondence to Robertas Kirlys, Institute of Dentistry, Zalgirio 115, Vilnius, Lithuania.
E-mail: rkirlys@gmail.com

pler and cheaper than electronic axiograph, however there are no studies to support its use in clinical work as a diagnostic tool.

The American Academy of Orofacial Pain (AAOP) even discourages using instrumental functional analysis for the purpose of diagnosing orofacial pain because of lack of scientific evidence [12].

On the other hand, the German Society for Dentistry and Orofacial Medicine attributes at least as much weight to instrumental functional analysis as to clinical findings [13, 14].

Having in mind the variance of opinion in the scientific literature, the objective of this study was to assess the ability of ARCUSdigma to describe the kinematics of diseased TMJs and determine which movement patterns is associated with a clinically (or by other methods) diagnosed joint pathology [15].

MATERIAL AND METHODS

From a group of patients attending consultations at Vilnius University Hospital "Zalgirio clinics" 56 subjects (8 males and 48 females) were selected for this investigation. The age of subjects ranged from 15 to 76 years old, with a mean age of 31,98. This comprised 102 temporomandibular joints.

All subjects underwent computerized axiography using "Cadiax Diagnostic" device and also temporomandibular joint examination using ultrasonic device ARCUSdigma (KaVo®) after proper history taking and assessment of clinical symptoms.

The data obtained using "Cadiax Diagnostic" and

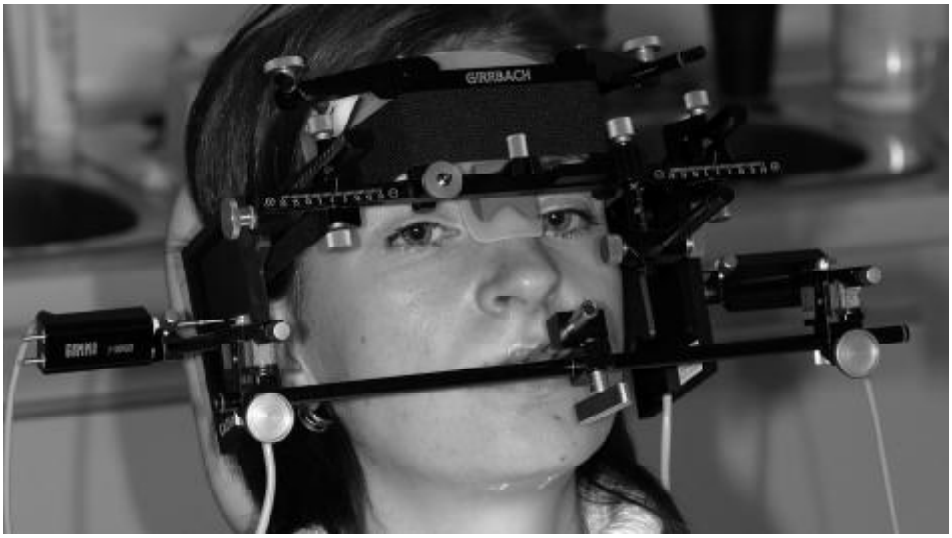

Fig. 1. Computerized axiography adjusted to head of patient

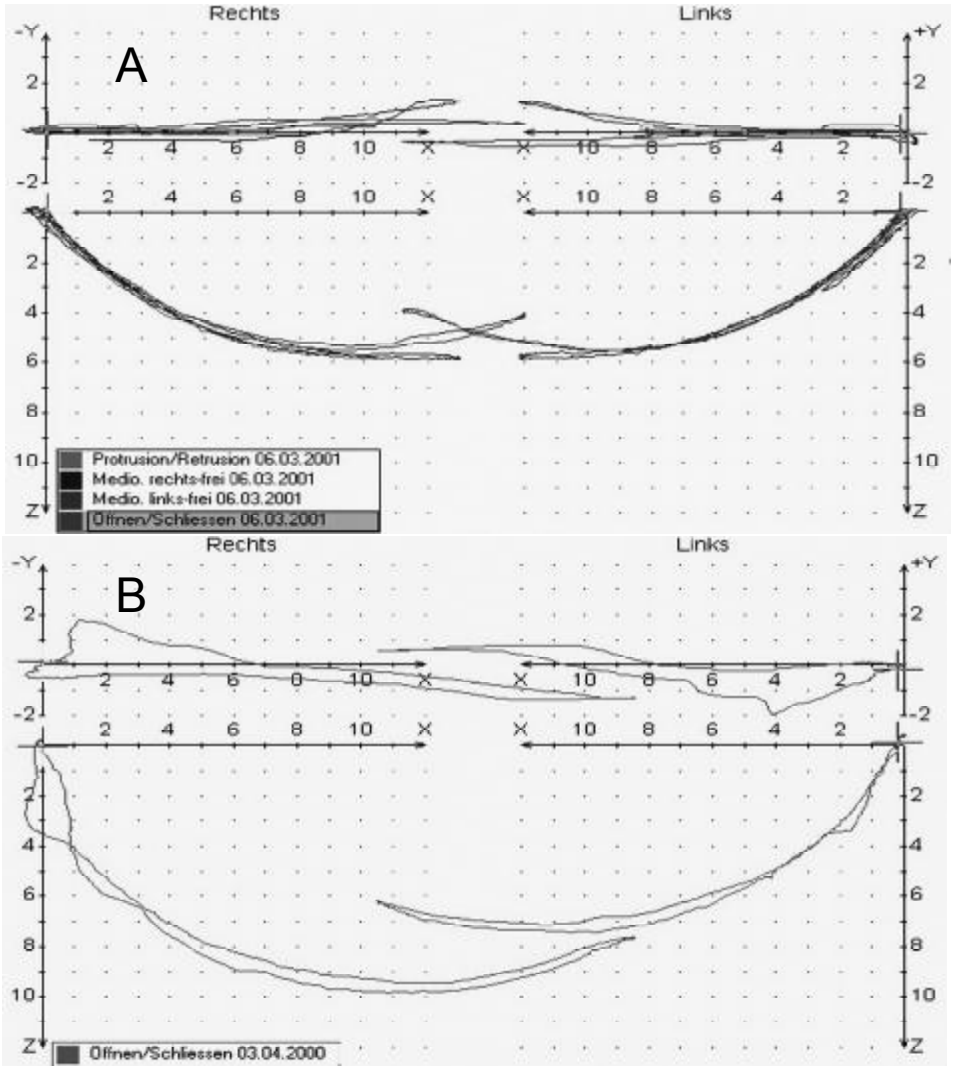

Fig. 3. A – left: Overlap of colour-coded axiograms of healthy joints; B – right: Opening/closing cycle on the right joint shows anterior disk displacement with early reposition (typical "figure eight") in the beginning of the movement

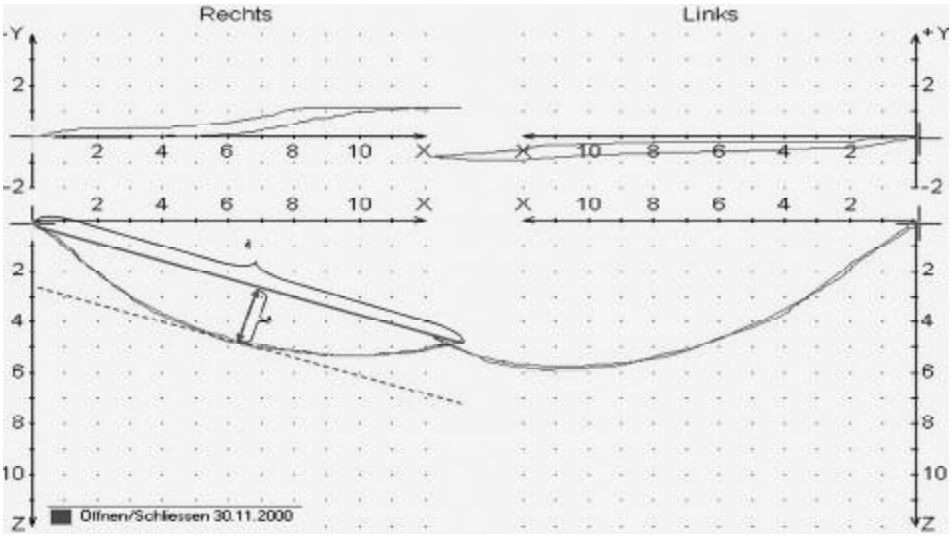

Fig. 2. Diagrammed determination of the of curvature coefficient on example of opening/closing cycle. Legend: d – Distance between the beginning and the finish point of movement recording (continuous red line); a – maximal deviation of the excursion or incursion curve from constructed straight line between the beginning and the finish point (see double red arrow)

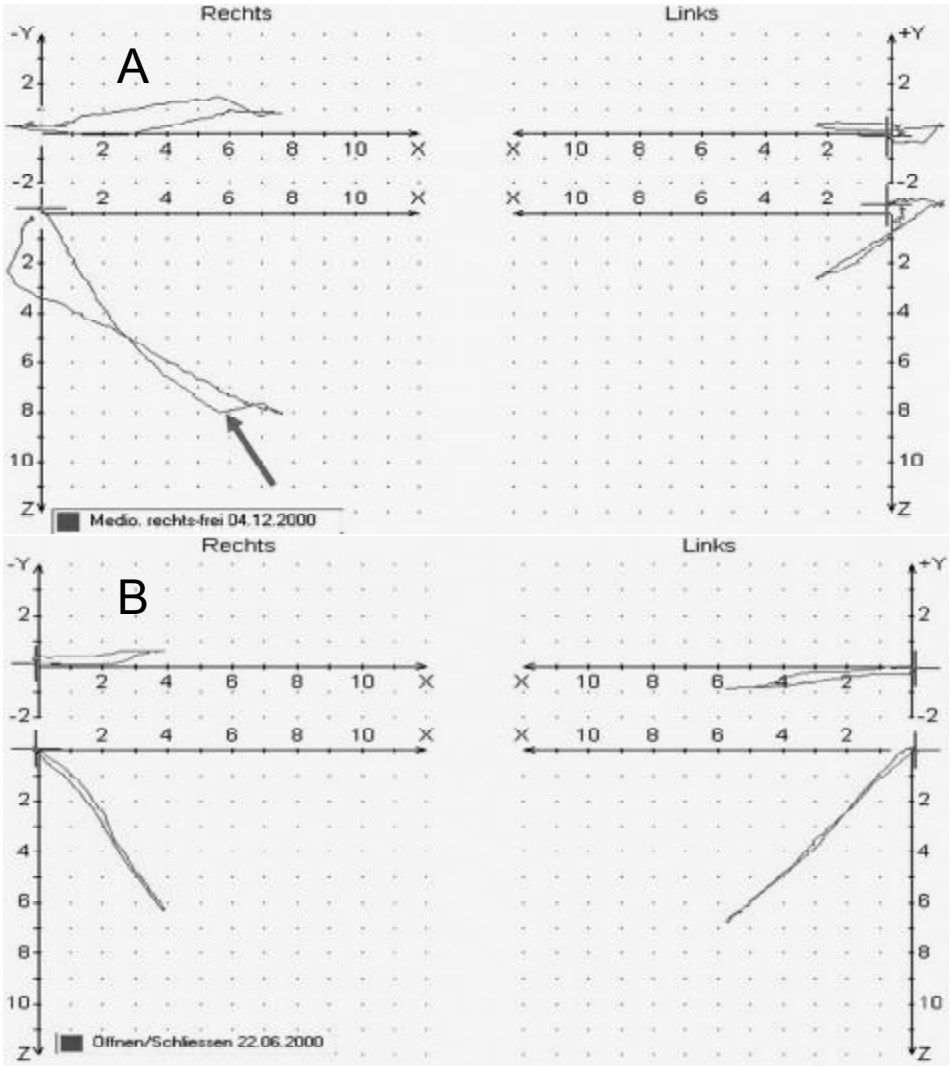

Fig. 4. A – left: Mediotrusive movement on the right joint shows typical "figure eight" creation of the late disk reposition at the end of the movement. Red arrow shows the repositioning time; B – right: Opening/closing cycle on the right joint is characterised as anteriorly convex, on the left joint as straight line cycle. In both TMJ there is strong suspicion of DDWR

ARCUSdigma were independently assessed by four diagnosticians. "Cadiax Diagnostic" was considered a standard in this study.

Interclass correlation coeficient (ICC) was calculated to validate the use of "Cadiax Diagnostic" as a standard. Sensitivity and specificity of ARCUSdigma in diagnosing temporomandibular joint pathology was evaluated by κ (kappa) koefficient. Better visualisation of results was done by graphics.

Electronic axiography diagnosis

The registration of TMJ tracings was made with the double face-bow "Cadiax Diagnostic" system (Gamma, Wien). Three-dimensionally adjustable lower bow is used to transmit hinge-axis movement of the mandible to the upper face bow (Fig 1).

In all cases the axiographic findings were recorded and assessed for both joints. One of the folowing diagnoses was made separately for left and right temporomandibular joints:

- no appreciable disease
- disk displacement with early reposition
- disk displacement with late reposition
- disk displacement without reposition
- non classifiable pathological change

Determination of the jaw-tracking curvature degree [11, 16]

For the evaluation of pathological changes in the following interpretation, the curvature, especially from opening/closing cycle and free protrusion cycle (X-and Z-axis), was a crucial factor. Convex curves were defined as definitely pathologic and their characteristics were not further analysed.

In the case of a concave curve it was necessary, to define it clearly from straight jaw-tracking in consideration to the curvature degree. Figure 2 shows determination of coefficient for the quantification of the flexion performance on opening/closing cycle recording.

For evaluation of maximal deviation the constructed straight line (red line between beginning and finish point of the movement recording) was displaced parallel downward (increasing Z-value), until it was tangent to the farthest point of movement recording (minor Z-value). From the distance between both straight lines (a) as well as from the length between beginning and finish point of movement recording (d) we get the curvature coefficient K as follows:

$$K = \frac{a}{d}$$

In the present examination we defined a limiting value of K = 0,05 (that is equivalent to a proportion of $\frac{a}{d} = \frac{1}{20}$).

In the case that the curvature coefficient lies around the limiting value ($0,04 \leq K \leq 0,06$), no evidence could be made due to the curvature in terms of pathological change. The outcomes of this are the following intervals:

$K < 0,04$
– straight line

$0,04 \leq K \leq 0,06$
– limit interval

$K > 0,06$
– curved track

Decision making in diagnosis

Due to the interpretation of the jaw-tracking devices the following suspecting diagnoses were made:

a) **"No appreciable disease"** described following criteria (Figure 3: a) left):

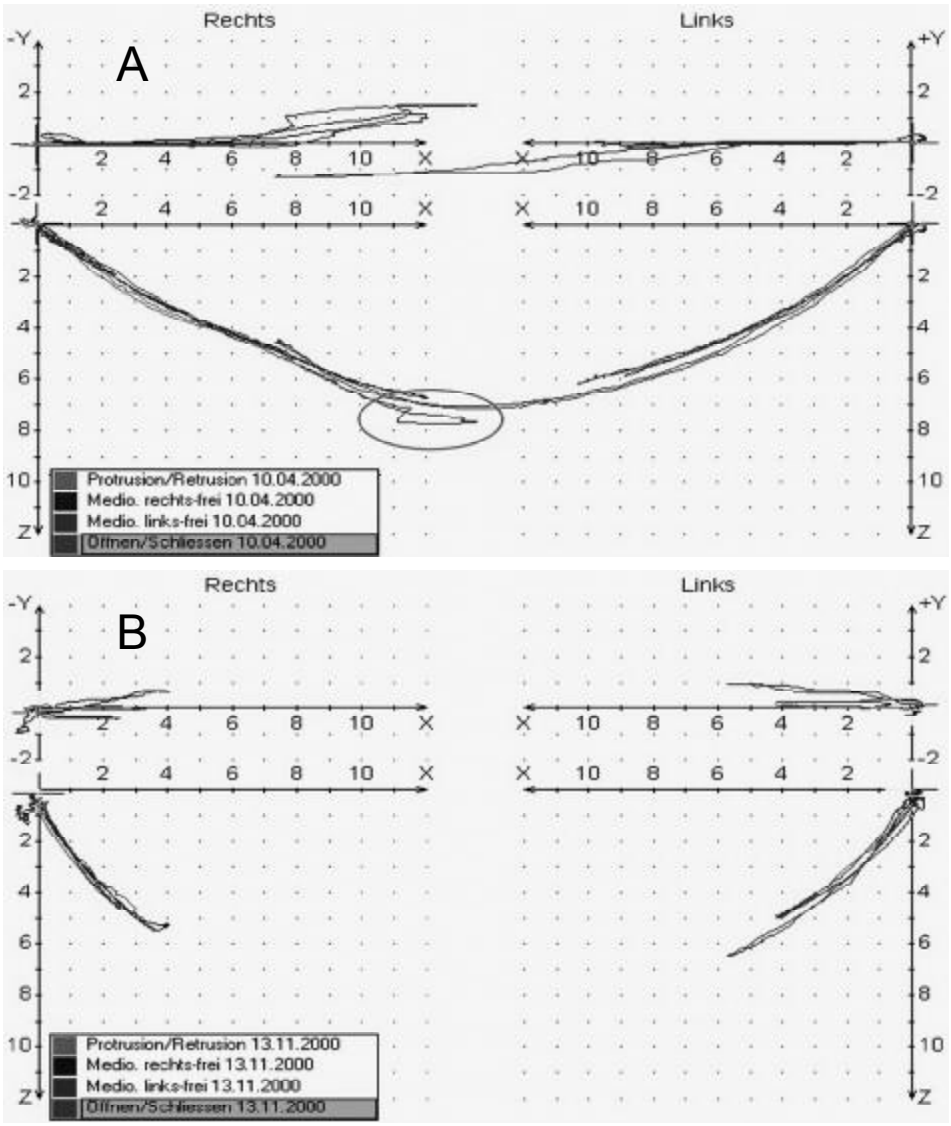

Fig. 5. a) left: disk displacement without reduction (right joint): Opening/closing cycle underflows mediotrusive und protrusive line (red circle); b) right: Both TMJs were signed with non-classifiable pathological change

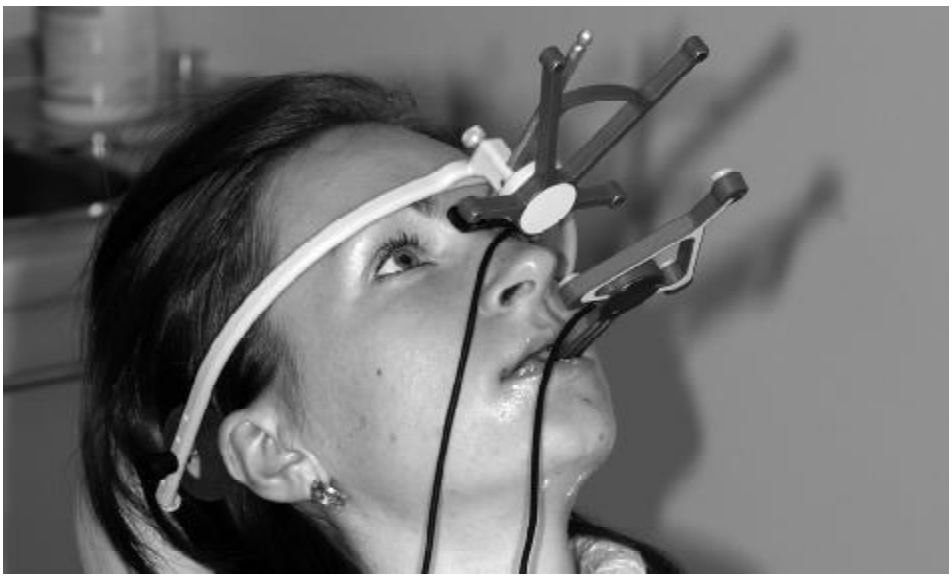

Fig. 6. Ultrasonic device ARCUSdigma adjusted to head of patient

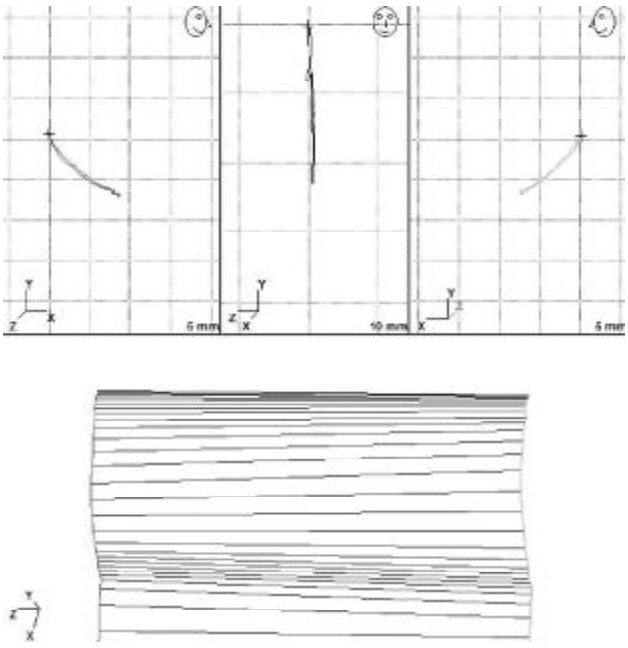

Fig. 7. "No appreciable disease"

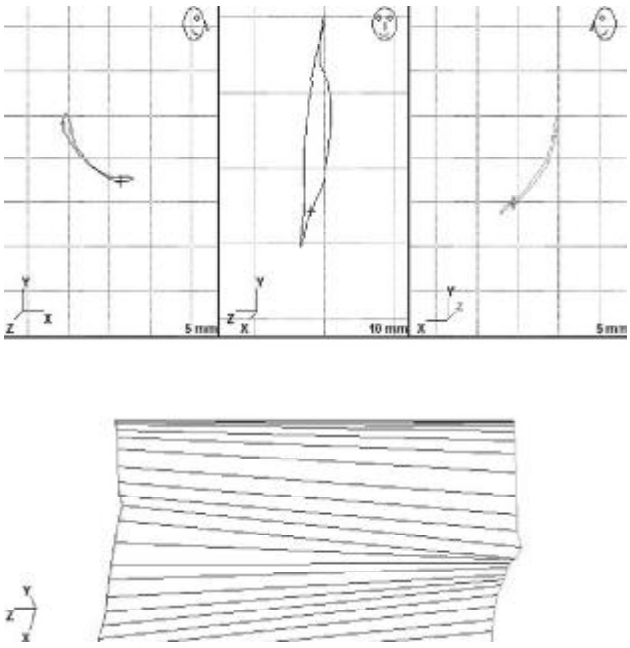

Fig. 8. "Disk displacement with early reposition"

- harmonically, reproducible, congruent cycles with anterior concavity;
- mediotrusive line is slightly longer than protrusive line and in the first 6-8 mm forms no Fischer angle;
- free and managed Bennett movements are ever positive and continuous;
- an average protrusive tracking length is about 8-10 mm, opening movement 10-12 mm and mediotrusive movement 12-14 mm;
- In the first 8 mm protrusive-, opening-, and mediotrusive cycles are normally coincident. Afterwards the opening line runs usually above.

b) **"Disk displacement with early reposition"** defined following criteria (Figure 3: b) right):

- typical „figure eight" creation from excursive and incursive cycles at the beginning area of coordinate system;
- partial deviation of excursive from the incursive line in the first 2 mm area of X- and Z-axis;
- negative value in the X-Axis at the and of intrusion movement.

c) **"Disk displacement with late reposition"** defined typical „figure eight" creation in the terminal phase of excursive und der incursive cycles (Figure 4: a) left).

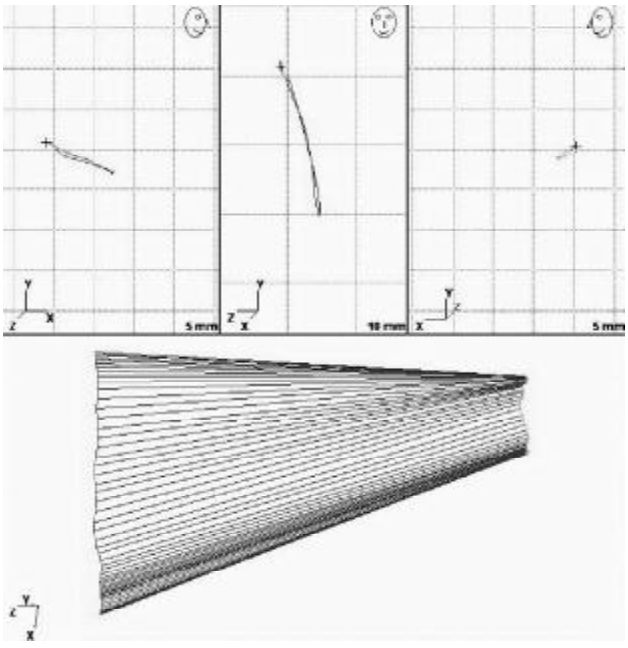

Fig. 9. "Disk displacement without reposition"

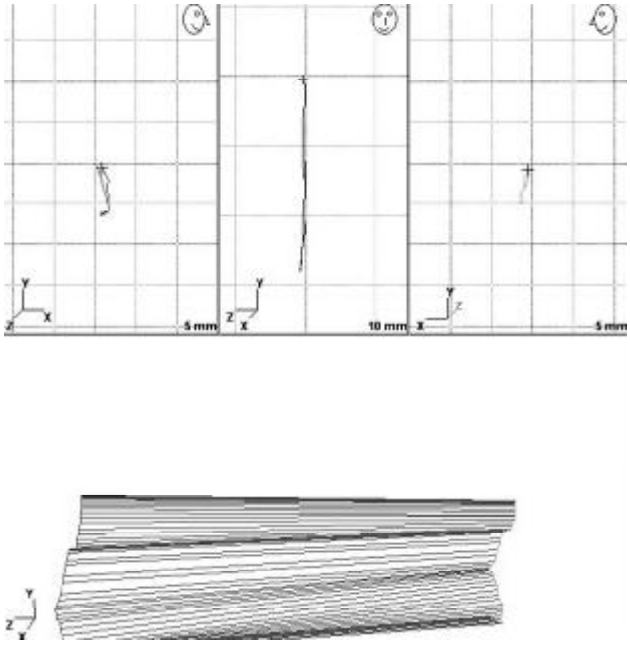

Fig. 10. "Non-classifiable pathological change"

d) In the evaluation of diagnosis **„disk displacement without reposition“** the focal point was the interpretation of the opening/closing cycles (Figure 4: b) right). In case of convex or straight line cycles (curvature coefficient K < 0,04) disk displacement without reposition (DDWR) was suspected diagnosis.

In case of a concave cycle with a curvature coefficient K on a limit interval (0,04 ≤ K ≤ 0,06), it was necessary to check coincidence of the opening/closing movement with those of the mediotrusive and protrusive tracks. In case of the opening/closing cycle underflowing the mediotrusive und protrusive movements, it was typical characteristic of disk displacement without reduction (Figure 5: a) left).

The concave cycle (K > 0,06) was characterized as physiological.

e) Cycles, where due to the interpretation criteria no clear diagnosis could be made, get the identification **„non-classifiable pathological change“** (Figure 5: b) right). At this point it has to be noted, that the most “struck disks“ hide under that coding. The typical characteristics of the cycles are limited, slightly concave, congruent curves.

Diagnosis using ultrasonic device ARCUSdigma

The registration of TMJ tracings was also made with the ARCUSdigma ultrasonic device (KaVo, Germany). Ultrasonic sender and receiver parts are used. First the position of the upper jaw is recorded. To register the lower jaw movements, the sender is fixed on the vestibular surfaces of lower anteriors with a paraocclusal aid (Fig. 6).

In all cases both joints were examined with ARCUSdigma. One of the folowing diagnoses was made separately for left and right temporomandibular joints:

- no appreciable disease
- disk displacement with early reposition
- disk displacement with late reposition
- disk displacement without reposition
- not classifiable pathological change

Determination of the jaw-tracking curvature degree

Since ARCUSdigma also provides graphical representation of the condylar movements in the form of curves, it was

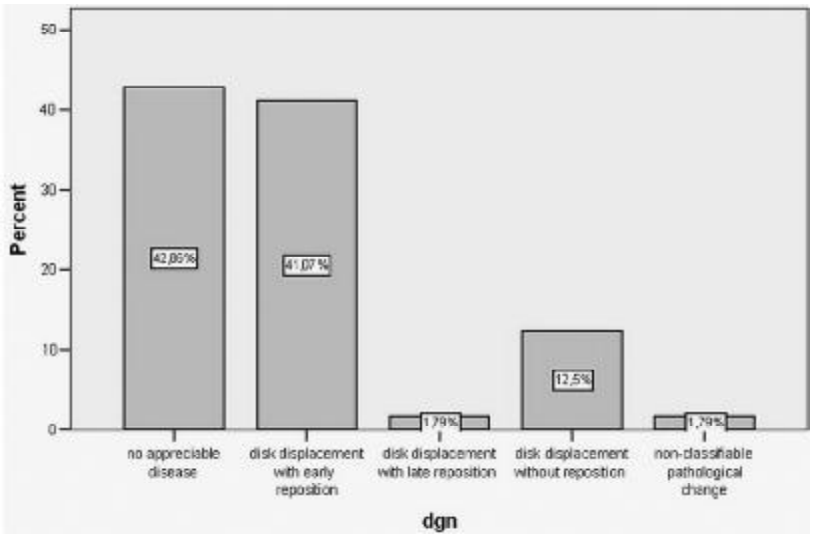

Fig. 11. Distribution of diagnoses for right TMJ based on "Cadiax Diagnostic" data

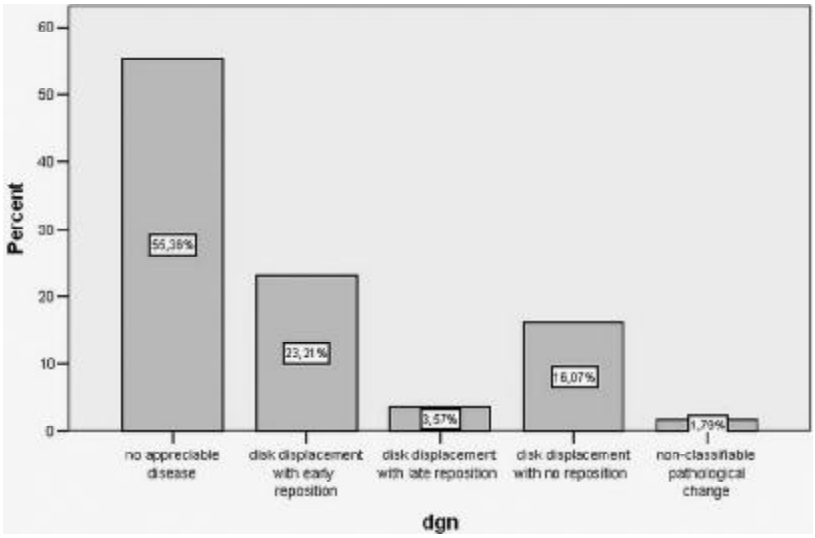

Fig. 12. Distribution of diagnoses for left TMJ based on "Cadiax Diagnostic" data

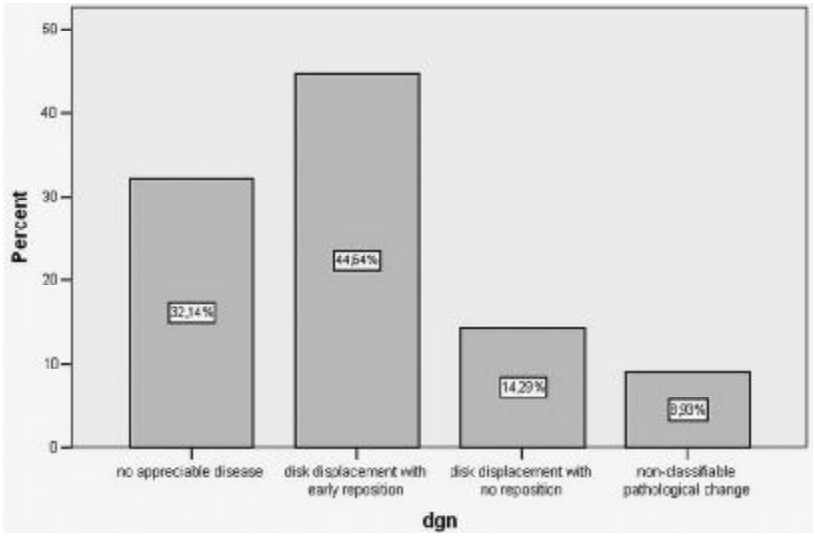

Fig. 13. Distribution of diagnoses for right TMJ based on ARCUSdigma data

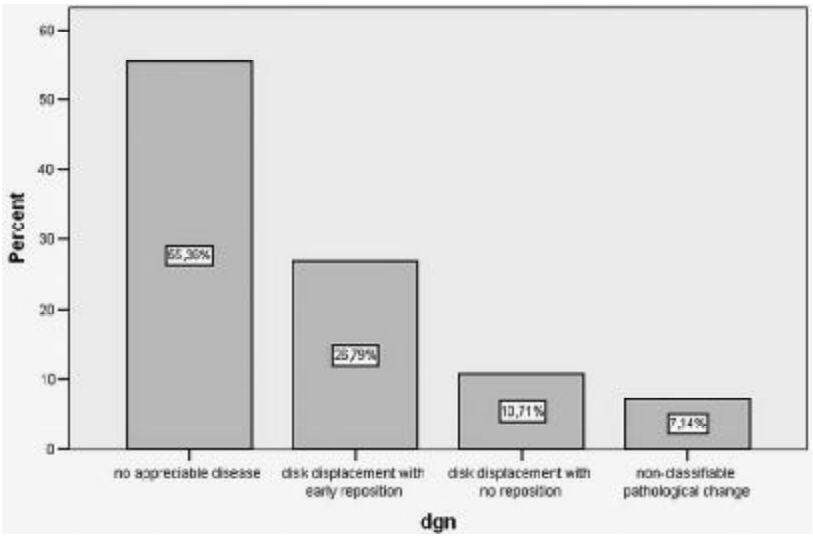

Fig. 14. Distribution of diagnoses for left TMJ based on ARCUSdigma data

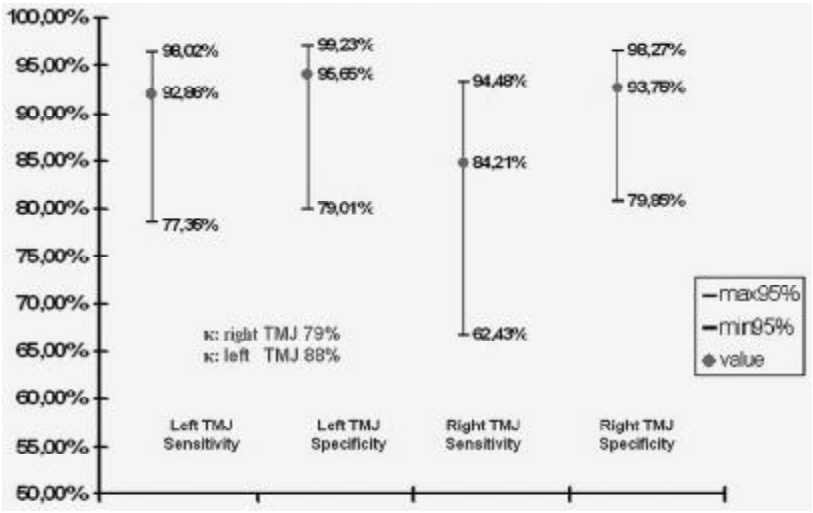

Fig. 15. Sensitivity, specificity values and kappa coeficient for ARCUSdigma

possible to use the same curvature coefficient K and similar criteria of decision making in diagnosis as described above for "Cadiax Diagnostic".

Decision making in diagnosis

Bellow typical examples of ARCUSdigma tracings are shown for each diagnostic group:

"No appreciable disease" (Fig. 7),

"Disk displacement with early reposition" (Fig. 8.),

"Disk displacement with late reposition"

There was not a single case with this diagnosis working with ARCUSdigma.

"Disk displacement without reposition"(Fig. 9),

"**Non-classifiable pathological change"**(Fig. 10)

RESULTS

The distribution of diagnoses made with "Cadiax Diagnostic" is shown in Figs. 11 and 12 for the right and left temporomandibular joints respectively.

As it is seen from the graphs, dominant diagnosis using data from "Cadiax Diagnostic" was disk displacement with early reposition. Pathology occuring in right temporomandibular joint was more comonly observed than in the left temporomandibular joint.

The distribution of diagnoses made with ARCUSdigma is shown in Figs. 13 and 14 for the right and left temporomandibular joints respectively.

For the right TMJ ARCUSdigma showed much less number of joints that could be asssigned to "no appreciable disease" group, only 32,14% compared to 42,86% "no appreciable disease" joints using "Cadiax Diagnostic" data. The number of TMJs diagnosed with "disk displacement with early reposition" was comparable showing values of 41,07% and 44,64% for "Cadiax Diagnostic" and ARCUSdigma respectively. ARCUSdigma was unable to detect joints having disk displacement with late reposition. The number of joints under "disk displacement with no reposition" diagnosis was higher with ARCUSdigma (14,29%) than with "Cadiax Diagnostic" (12,5%). Diagnosis of "non-classifiable pathological condition" was also more often made with ARCUSdigma (8,93%) than with "Cadiax Diagnostic" (1,79%).

For the left TMJ the number of joints with no appreciable pathology was equal with both devices reaching 55,36%. Disk displacement with early reposition was more commonly diagnosed with ARCUSdigma (26,79%) than with "Cadiax Diagnostic" (23,21%). There was no "disk displacement with late reposition" group using ARCUSdigma on the left side. The absence of this group was observed on the right side too. Using ultrasonic device some disk displacements without reposition were left undetected, the numbers reaching 16,07% and 10,71% with "Cadiax Diagnostic" and ARCUSdigma respectively. However a diagnosis of non-classifiable pathologic change could be reached more often using ARCUSdigma (7,14%) than "Cadiax Diagnostic" (1,79%).

Sensitivity and specificity values (including 95% confidence intervals) of ARCUSdigma were calculated, equivalence of two diagnostic devices was evaluated by κ (kappa) coeficient. The results are shown in Fig.15.

High sensitivity and specificity values shown in the graph above were for differentiating between "no appreciable disease" and any pathologic condition in

the joint. High kappa coeficient of 79% and 88% for the right and left temporomandibular joints respectively were also calculated when differentiating "healthy" from diseased. According to the kappa coeficient equivalence of two diagnostic devices in differentiating "healthy" from "diseased" TMJs was deemed excellent.

DISCUSSION

Patients were selected for the study on the basis of previous or present clinical symptoms, such as pain in TMJ, clicking and/or crepitation, limited opening. All subjects underwent computerized axiography using "Cadiax Diagnostic" device and also temporomandibular joint examination using ultrasonic device ARCUSdigma after proper history taking and assessment of clinical symptoms. A total number of 128 TMJs were examined. 102 pairs of TMJ tracings were left for final examination. Each pair of tracings was recorded during the same visit. First examination was performed with "Cadiax Diagnostic", second one with ARCUSdigma. Tracings of 26 TMJs were discarded, because patients had no clinical symptoms and instrumental examination was performed only to obtain data for fully adjustable articulators. Electronic axiograph "Cadiax Diagnostic" can record more movements than ARCUSdigma (including speech, bruxing, MPI and guided movements), so only the movements that both devices can record were chosen. Calibration of four examiners was performed using tracings of 40 TMJs (29 diseased, 11 no appreciable disease). Common percent of coincidence of 93% (kappa 81%, 82%, 83%, 83%) was found.

Electronic axiograph "Cadiax Diagnostic" is considered a valuable and reliable tool to aid in making diagnosis and comparable to MRI according to literature, so it was chosen as a reference in this study. In a study by Kobs G. [11] electronic axiograph was compared to MRI, which has high sensitivity of 67-100% according to autopsy studies. Sensitivity of "Cadiax Diagnostic" was 75,8% and 80,7% for left and right TMJ respectively and specificity 90,7% and 82,8% for left and right TMJ respectively. It is proven that electronic axiography is better at differential diagnosis of dynamic dysfunction than MRI [17, 18]. Interclass correlation was calculated to check the reliability of "Cadiax diagnostic" data. The result approximately being equal to 1, "Cadiax Diagnostic" was considered reliable.

Writing this article we had only six studies [19, 20, 21, 22, 23, 24] available where ARCUSdigma was used. In three of them the device was only used as an adjunctive tool and was not a subject of study itself. In other three studies ARCUSdigma was used as an additional patient examination tool besides medical and dental history taking, clinical examination and radiological examination. However in none of those studies available to us sensitivity and specificity of the device was determined. Also the reliability of ARCUSdigma data was not determined using autopsy or MRI data, which best represent joint anatomy. The only study were reliability of ARCUSdigma data was evaluated was performed not in clinical setting but using predetermined values on articulators that were measured with ARCUSdigma.

Same measurements can be performed using both devices. Hinge axis – orbital reference plane is used by "Cadiax Diagnostic"and camper horizontal by ARCUSdigma. However it does not affect the diagnosis.

ARCUSdigma was shown to be highly specific and sensitive in differentiating between healthy and diseased joints, however it performed worse when used for differential diagnosis. These results conform with Kiss G. et al. [19], who conclude that ARCUSdigma is a good additional tool to examine patients with TMJ dysfunction however it cannot replace ordinary diagnostic methods, and with Kobs G., Bernhardt O., Meyer G. [25].

Piehslinger [26] and Gsellmann et al. [27] see a special significance for axiography in the visual presentation of dysfunctional dynamics and the strength of MRT in the diagnosis of morphologic alterations. They suggest combining the two methods, in order to obtain a comprehensive evaluation of functional disorders in the stomatognathic system

However the results presented offer some contradictions to Lückerath et al. [28], Rammelsberg et al. [29] and Rozencweig [30], who were the first to show that tentative diagnoses, based on axiography often did not correspond with findings from MRT. Also, Bumann and Groot-Landeweer [31] could determine correspondence between the two methods in only 42% of the cases, whereby posterior discus displacement and discus adhesions did not correspond in any of the cases studied. Anterior discus dislocation without repositioning was correctly diagnosed in 43% of the cases and non-pathologic findings were correctly diagnosed in 35% of the cases.

Mohl et al. [32] and Türp [33] also doubted the diagnostic value of mandibular movement registration (because of the contradictory data in the literature).

Lund et al. [34] pointed out, that registrations of active mandibular joint movements, irregardless of the device, were so non-specific, that neither the registration, nor the attempt at interpreting the tracks, was meaningful for differential therapy. His opinion was that these systems could still be useful, however, for scientific problem-solving in isolated cases.

CONCLUSION

Ultrasonic axiograph registrations of mandibular movements, in the framework of instrumental functional diagnostics of the masticatory organ, appeared to be a valuable supplement to clinical findings. How-

ever it should not be solely relied on in making differential diagnosis and the direct assessment of axiography tracks should be concerned less with wanting to obtain definite indications whether the patient being examined is functionally healthy or sick, but rather with determining which movement pattern is associated with a clinically (or by other methods) diagnosed joint pathology [24].

REFERENCES

1. Murakami S, Takahashi A, Nishiyama H, Fujishita M, Fuchihata H. Magnetic resonance evaluation of the temporomandibular joint disc position and configurtion. *Dentomaxillofac Radiol* 1993; 22: 205-7.
2. Piehslinger E, Babka A, Wegscheider WA, Slavicek R. Elektronische Axiographie zur standartisierten Diagnostik der Kiefergelenkbewegung. *Inf Orthod Kieferorthop* 1992a;24:205-20.
3. Hüls A, Walter E, Kuper K, Schmelzle R. Internal derangements of the TMJ and their visualization by NMR imaging. *Dtsch Z Mund Kiefer Gesichtschir* 1987;11:328-32.
4. Hugger A. Diagnostic imaging assessment of temporomandibular joint pain. *Schmerz* 2002;16:355-64.
5. Rammelsberg P, Pospiech P, May HC, Gernet W. Evaluation of diagnostic criteria from computerized axiography to detect internal derangements of the TMJ. *Cranio.*1996;14:286-95.
6. Lemke AJ, Griethe M, Peroz I, Lange KP, Felix R. Morphometric analysis of the temporomandibular joint with MRI in 320 joints. *Rofo* 2005;177:217-28.
7. Emshoff R, Innerhofer K, Rudisch A, Bertram S. Clinical versus magnetic resonance imaging findings with internal derangement of the temporomandibular joint: an evaluation of anterior disc displacement without reduction. *J Oral Maxillofac Surg* 2002;60:36-41.
8. Okeson JP.Management of temporomandibular disorders and occlusion. Mosby: St Luis; 2003.
9. Meyer G. Entwicklung und Anwendung eines elektronischen Verfahrens zur dreidimensionalen scharnierachspunktbezüglichen Registrieren von Unterkieferbewegungen für die Funktionsdiagnostik des stomatognathen Systems. Habilitationsschrift. Göttingen; 1986.
10. Meyer G. Elektronishes Registrieren der Unterkieferbewegungen und der Kiefergelenkfunktion. Siebert G.K. (Hrsg): Atlas der zahnärztlichen Funktionsdiagnostik. München: Hanser-Verlag; 1996. S.271-88.
11. Kobs G. Differentialdiagnostische Aspekte bei der Beurteilung von Funktionstörungen des stomatognathen Systems mittels elektronischer Achsiographie und Magnetresonanztomographie. 2003.
12. Okeson JP. Orofacial Pain. Guidelines for Assessment, Diagnosis, and Management. Chicago: Quintessence; 1996.
13. Freesmeyer WB, Koeck B., Reiber T. Stellungnahme der DGZMK. Zur Therapie der funktionellen Erkrankungen des Kauorgans. *Zahnärztl Mitt* 1998;88:3185-6.
14. Engelhardt JP, Hugger A, Jakstat HA, Kordaß B. Instrumentelle Funktionsanalyse – Prinzipien und Anwendung. Deutsche Gesellschaft für Zahn- Mund- und Kieferheilkunde;2002.
15. Zimmer B, Treichel A, Kubein-Meesenburg D. Achsiographische Auffälligkeiten in Patientengruppen mit klinisch unterschiedlichen Funktionszuständen. *Dtsch Zahnärztl Z* 1990;45:78-82.
16. Slavicek R. The Masticatory Organ.2002.
17. Piehslinger E, Schimmerl S. Celar A, Crowley C, Imhof H. Comparison of magnetic resonance tomography with computerized axiography in diagnosis of temporomandibular joint disorders. *J Oral Maxillofac Surg* 1995;24:13-9.
18. Gsellmann B, Kaida A, Paur T, Knaus A, Slavicek R. Vergleich der Befunde aus klinischer und instrumenteller Funktionsanalyse des Stomatognathen Systems. *Stomatologie* 1998;95:383-6.
19. Kiss G, Kiss P, Pacz M. Functional investigation of the stomatognathic system attached to an ultrasound computer module. *Fogory Sz*. 2005;98: 145-52.
20. Baker PJ, Setchell DJ, Tredwin CJ. Reproduction of articulator settings and movements with an ultrasonic jaw movement recorder. *Eur J Prosthodont Restor* 2006;14:55-62
21. Cheng HJ, Chen YQ, Geng Y, Zhang FQ. The effect of the position of artificial premature on mandible moving track during opening movement. *Shanghai Kou Oiang Xue* 2006;15:356-9.
22. Li HB, Wu GX, Zhang H, Feng HL, Li YS. The preliminary study of three-dimensional simulation of the craniofacial system. *Zhonghua Kou Oiang Yi Xue Za Zhi* 2005; 40: 405-7.
23. Bakalczuk M, Bozyk A, Iwanek M, Borowicz J, Sykut J, Kleinrok J. Diagnostic abilities of three-dimensional electronic axiography on the basis of ARCUSdigma device. *Ann Univ Mariae Ciuri Sklodowska Med* 2004;59: 324-7.
24. Stiesch-Scholz M., Demling A., Rossbach A.: Reproducibility of jaw movements in patients with craniomandibular disorders. *J Oral Rehabil* 2006;33:807-12.
25. Kobs G, Bernhardt O, Meyer G. Accuracy of Computerized Axiography Controlled by MRI in Detecting internal derangements of the TMJ. *Stomatologija* 2004;6:7-10.
26. Piehslinger E, Schimmerl S, Celar A, Crowley C, Imhof H. Comparison of magnetic resonance tomography with computerized axiography in diagnosis of temporomandibular joint disorders. *J Oral Maxillofac Surg* 1995;24:13-9.
27. Gsellmann B, Kaida A, Paur T, Knaus A, Slavicek R. Vergleich der Befunde aus klinischer und instrumenteller Funktionsanalyse des Stomatognathen Systems. *Stomatologie* 1998;95:383-6.
28. Lückerath W, Leiendecker U, Krahe T, Gieseke J, Dewes W. Zur Diagnostik funktioneller Störungen des Kiefergelenks. *Dtsch Zahnärztl Z* 1988;43:71-8.
29. Rammelsberg P, Gernet W, Neumaier U. Zur Differentialdiagnose reziproker Knackphänomene mit Hilfe der elektronischer Achsiographie (SAS). *Dtsch Zahnärztl Z* 1990;45:61-4.
30. Rozencweig G. Evaluation comparative de deux moyens d'investigation des dysfonctions cranio-mandibulaires: l´achsiographie et l'imagerie en resonance magnetique. *Rev Orthop Dento Faciale* 1991;25:205-13.
31. Bumann A, Groot-Landeweer G.: Reziproke Knackphänomene. Zuverlässigkeit der Axiographie. *Phillip J* 1991;91:377-80.
32. Mohl ND, McCall WD, Lund JP, Plesh O. Devices for the diagnosis and treatment of temporomandibular disorders. Part I: Introduction, scientific evidence, and jaw tracking. *J Prosthet Dent* 1990;63:198-201.
33. Türp JC. Myoarthropathien des Kausystems – mehr als nur ein zahnmedizinisches Problem. *Dtsch Med Wschr* 1997; 122: 483-7.
34. Lund JP, Widmer CG, Feine JS. Validity of diagnostic and monitoring tests used for temporomandibular disorders. *J Dent Res* 1995;74:1133-43.

Received: 17 04 2007
Accepted for publishing: 17 07 2007