An assessment of the usefulness of jaw kinesiography in monitoring temporomandibular disorders

Correlation of treatment-related kinesiographic and pain changes in patients receiving temporomandibular joint injections

Daniele Manfredini, DDS, PhD; Lorenzo Favero, MD, DDS; Matteo Michieli, DDS; Luigi Salmaso, PhD; Francesco Cocilovo, DDS; Luca Guarda-Nardini, MD, DDS

Temporomandibular joint (TMJ) disorders are characterized by a classic triad of signs and symptoms: pain, joint sounds and functional limitation.[1] Their treatment usually is directed toward the achievement of symptom management and pain relief by means of conservative approaches.[2] Because the assessment of pain is a fundamental step in the diagnostic process as well as a target for therapy, treatment outcome measures should be based on monitoring pain symptoms.[3] According to this premise, all instrumental approaches to the diagnosis and monitoring of TMJ disorders should prove to be reliable for discriminating between patients with and without pain as well as for detecting changes in pain levels across time.

Dr. Manfredini is an assistant professor, TMD Clinic, Department of Maxillofacial Surgery, University of Padova, Italy. Address reprints to Dr. Manfredini, Viale XX Settembre 298, 54033 Marina di Carrara (MS), Italy, e-mail daniele.manfredini@tin.it.
Dr. Favero is a professor, School of Dentistry, University of Padova, Italy.
Dr. Michieli is a clinical fellow, School of Dentistry, University of Padova, Italy.
Dr. Salmaso is a professor, Department of Management and Engineering, University of Padova, Italy.
Dr. Cocilovo is an assistant professor, School of Dentistry, University of Padova, Italy.
Dr. Guarda-Nardini is an assistant professor and the director, TMD Clinic, Department of Maxillofacial Surgery, University of Padova, Italy.

ABSTRACT

JADA CONTINUING EDUCATION ARTICLE 2

Background. The authors conducted a study in patients with temporomandibular joint (TMJ) osteoarthritis to assess whether treatment-related changes in pain levels and chewing ability coincide with a change in jaw kinesiographic (KG) parameters.

Methods. The authors selected 34 patients with a diagnosis of TMJ osteoarthritis that met Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) to undergo a cycle of five weekly arthrocentesis procedures with injections of 1 milliliter hyaluronic acid. They performed a permutation test to assess the correlation between changes across time (from baseline to end of treatment) in two clinical outcome parameters—pain level and chewing ability—and changes across time in the KG outcome parameters.

Results. The authors observed improvement across time in both chewing ability ($F = 8.328$; $P = .005$) and pain level ($F = 10.903$; $P = .002$). The authors observed no significant changes in any KG variables. With minor exceptions, no significant correlations were shown between changes in the clinical and KG parameters during the treatment period.

Conclusions. Treatment-related changes in pain levels and chewing ability in patients with TMJ osteoarthritis do not coincide with changes in KG parameters.

Practical Implications. If one assumes pain variables to be the primary outcome measures in assessing treatment of TMJ osteoarthritis, KG recordings of the jaw are not useful for monitoring TMJ osteoarthritis in the clinical setting.

Key Words. Temporomandibular disorders; kinesiography; temporomandibular joint arthrocentesis; hyaluronic acid; pain.

JADA 2013;144(4):397-405.

Through the years, several technological devices have been proposed as diagnostic tools or instruments to measure treatment effectiveness.[4-6] Among these, jaw-tracking devices for kinesiographic (KG) recordings of jaw movements were intended to provide an objective evaluation of mandibular motion,[7] and their adoption was recommended by panels of trained users as an approach to detect dysfunction of the stomatognathic system.[8] Notwithstanding that, the devices' diagnostic accuracy for temporomandibular disorders (TMD) never has been proven to be good.[9] Recent investigations involving commercially available devices suggested that a combination of surface electromyography (EMG) and KG assessment does not reliably detect pain in the jaw muscles[10] and that KG recordings lack acceptable reliability in identifying patterns of jaw movements in relation to the TMJ status.[11] Another potential use for such techniques is at the intraindividual level to monitor treatment effects. Thus, it should be interesting to evaluate the correlation of treatment-related pain changes with modifications in KG parameters.

Does a treatment-related change in pain level and chewing ability coincide with a change in any kinesiographic parameters?

We conducted a study in patients with TMJ osteoarthritis who were receiving a treatment protocol involving a cycle of five weekly arthrocenteses plus hyaluronic acid injections for pain relief and improved subjective chewing ability (as suggested in previous research findings[12-14]). Participants underwent KG recordings of jaw movements at baseline and at the end of the treatment. Our working hypothesis was that the protocol involving injection of an osteoarthritic joint would produce changes in clinical parameters (that is, pain level and chewing ability) related to changes in the KG parameters of mouth opening and jaw-movement speed. Specifically, we designed the study protocol to answer the following clinical research question: does a treatment-related change in pain level and chewing ability coincide with a change in any KG parameters?

METHODS

Study design. The study participants were 34 patients (94 percent female, mean age 55.7 years, range 39-76 years) who had monolateral TMJ osteoarthritis, as diagnosed according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD Axis I Group IIIb),[15] in the absence of rheumatic diseases. All were patients at the TMD Clinic, Department of Maxillofacial Surgery, University of Padova, Italy. To meet the RDC/TMD criteria for osteoarthritis, participants needed to have the following symptoms:

- arthralgia (TMJ pain on lateral or posterior palpation or both, as well as anamnestical reporting of TMJ pain during maximum voluntary mouth opening, maximum assisted mouth opening, lateral excursions or a combination of these);
- crepitus sounds;
- radiological signs of TMJ bone structure abnormalities (such as erosions, sclerosis, flattening, osteophytes).

As for radiological signs, Dworkin and LeResche's[15] 1992 publication of the RDC/TMD diagnostic criteria allowed only plain tomography and panoramic radiographs to support the clinical diagnosis of osteoarthritis. In our investigation, plain radiographs already were available for some participants at the time of the first assessment. In some other participants, we obtained cone-beam computed tomographic scans to integrate the clinical diagnosis, despite this technique's obviously not being available at the time of the RDC/TMD guidelines' initial publication.[15] All participants had a history of pain lasting for more than six months that either was not improving or was improving only minimally with conservative physiotherapy or oral appliance therapy provided by their practitioners. The presence of jaw muscle pain was not an exclusion criterion, provided that it was not the main source of patients' complaints.

The treatment protocol involved a cycle of five arthrocentesis procedures, one per week for five weeks, each accompanied by an injection of 1 milliliter of hyaluronic acid (Sinovial, IBSA Farmaceutici Italia, Lodi, Italy) according to the technique described by Guarda-Nardini and colleagues.[12] All interventions were performed by two trained operators with experience in the procedure (D.M., L.G.-N.). All participants gave written informed consent to the treatment received before taking part in the study. The operators performed both a clinical and a jaw KG assessment at baseline and at the end of the

ABBREVIATION KEY. EMG: Electromyography. **KG:** Kinesiography/Kinesiographic. **RDC/TMD:** Research Diagnostic Criteria for Temporomandibular Disorders. **TMD:** Temporomandibular disorder. **TMJ:** Temporomandibular joint.

treatment. The treatment protocol was part of the clinical activities of the TMD clinic and was approved by the medical director and the review board of the University of Padova, Italy.

Clinical parameters. The following clinical pain-related parameters, which researchers in previous investigations[12-14] usually adopted as markers of treatment effectiveness, were assessed by the same operator (M.M.) at the time of the diagnosis and at the end of the five-week treatment:

- TMJ pain levels, assessed by means of a visual analog scale (VAS) that ranged from 0 to 10, with the extremes being "no pain" and "pain as bad as the patient ever experienced," respectively;
- chewing ability, assessed by means of a VAS that ranged from 0 to 10, the extremes of which were "eating only semiliquid food" and "eating solid hard food."

To increase the internal validity of findings, the examiner who recorded the clinical parameters was masked with respect to the findings of jaw KG.

Patients with temporomandibular disorders who need treatment may have different characteristics, but they share a major trait: they feel pain.

KG assessment. All study participants underwent two KG recordings, one at baseline and one at the end of treatment, with a commercially available device for measuring and recording mandibular function (K6 Diagnostic System, Myotronics, Seattle). All KG assessments were made by an investigator (F.C.) who had expertise in the use of such devices and who received training at in-house courses organized by the manufacturer. The investigator was masked with respect to the clinical parameters. During all examinations, which the investigator performed in strict observance of the manufacturer's guidelines, the participant was seated on a wooden high-backed chair, with his or her trunk perpendicular to the floor and head upright. The KG recordings were made with the use of a magnet temporarily positioned on the participant's buccal mucosa under the mandibular central incisors to monitor the location of the mandible against a sensor array suspended in front of the face by a lightweight frame placed on the bridge of the nose and connected behind the head by straps. The participant performed all tasks three times at 10-minute intervals, and the investigator recorded the average value of the three attempts. For speed-assessment tasks, the investigator asked the participant to perform movements at the highest possible speed and recorded the maximum and average speed during jaw-opening and jaw-closing movements. For all participants, the investigator recorded data for the following parameters:

- maximum mouth opening (in millimeters);
- maximum lateral deviations from the midsagittal plane during jaw opening (in mm);
- maximum and average speed during jaw-opening and jaw-closing movements (in mm/second);
- maximum speed at the end of the closing movement (teeth-contact point) (in mm/second).

Statistical analysis. We managed all clinical and KG parameters as continuous variables. We performed a single-variable correlation analysis at baseline to assess the correlation between the clinical parameters (pain level and chewing ability) and the KG variables (maximum mouth opening; maximum lateral deviations from the midsagittal plane during jaw opening; maximum and average speed during jaw-opening and jaw-closing movements; maximum speed at the end of the closing movement). Then we performed an analysis of variance (ANOVA) for repeated measures to assess changes across time (from baseline to end of treatment) in all the study parameters. As a further step in the statistical analysis, we performed a permutation test to assess the correlation between changes across time in the clinical outcome parameters and the KG outcome parameters. The permutation test was designed to test the null hypothesis that a treatment-related change in pain level and chewing ability does not coincide with correlated changes in KG-recorded parameters. Specifically, the expected results were that if pain decreased and chewing ability improved, jaw-movement speed and mouth opening would increase. Then we performed a single-variable correlation analysis at the end of treatment to assess the correlation between the clinical and KG variable parameters.

We performed all the statistical procedures by using statistical analysis software (SPSS Version 19.0, IBM SPSS, Armonk, N.Y.). For all the analyses, we set statistical significance at $P < .05$.

RESULTS

Single-variable correlation analysis showed that chewing ability was not related to findings in any KG variables at baseline (P values ranging from .262 to .664). As for pain levels, we found correlations at baseline with average and max-

TABLE 1

Single-variable correlation analysis between kinesiographic and clinical parameters at baseline.

KINESIOGRAPHIC PARAMETER	CORRELATION WITH BASELINE VALUE (*P*)	
	Chewing Ability	Pain Level
Mouth Opening (Millimeters)	0.139 (.43)	0.141 (.42)
Maximum Left Deviation (mm)	−0.077 (.66)	0.032 (.85)
Maximum Right Deviation (mm)	0.171 (.33)	0.126 (.48)
Maximum Jaw-Opening Speed (mm/Second)	0.198 (.26)	−0.361 (.03)*
Average Jaw-Opening Speed (mm/Second)	0.119 (.50)	−0.438 (.01)*
Maximum Jaw-Closing Speed (mm/Second)	0.158 (.37)	−0.274 (.11)
Average Jaw-Closing Speed (mm/Second)	0.152 (.39)	−0.292 (.09)
Maximum Speed at Teeth-Contact Point (mm/Second)	0.108 (.54)	−0.418 (.01)*

* Significant at $P < .05$.

imum jaw-opening speed and with maximum speed at teeth-contact point ($P < .05$) (Table 1).

ANOVA for repeated measures showed that significant changes were described at the end of the treatment for both clinical variables, chewing ability ($F = 8.328$; $P = .005$) and pain level ($F = 10.903$; $P = .002$). No significant changes were described in any of the KG variables at the end of treatment (Table 2). Table 3 (pages 402 and 403) shows treatment-related changes at the individual level.

A permutation test assessing the correlation of treatment-related changes in clinical and KG parameters showed that improvement in chewing ability was correlated with increases in mouth opening ($r = 0.388$; $P < .05$), and that both pain levels ($r = 0.358$) and chewing ability ($r = 0.366$) were correlated with changes in maximum left deviation during mouth opening ($P < .05$). No correlations were shown between any of the other clinical and KG parameters (Table 4, page 404).

At the end of treatment, we found no correlations between the clinical variables and any of the KG parameters (P values ranging from .17 to .92) (Table 5, page 404).

On the basis of the aforementioned findings, we could not reject the null hypothesis that changes in KG parameters for mouth opening and jaw-movement speed were not related to changes in pain level and chewing ability.

DISCUSSION

The use of technological devices in the field of TMD diagnosis and treatment, despite claims that instruments can help measure the rate of dysfunction in patients with TMD, so far has been based on empirically driven suggestions rather than on scientifically proven premises.[16] Thus, criticism has been raised by the scientific community regarding the widespread adoption of devices intended to measure purported neuromuscular, KG or postural imbalances or a combination thereof.[17] In particular, a common shortcoming of the literature about technological devices in the field of TMD is the absence of focus on the patient's symptoms. Patients with TMD who need treatment may have different characteristics, but they share a major trait: they feel pain. On the basis of this premise, it seems logical that efforts be directed to assess an instrument's validity in discriminating between patients with and without pain, assuming that an instrumental sign cannot be considered a pathological marker per se unless it has a relationship with a clinical symptom.

In our study, we attempted to assess the correlation between treatment-related changes in impairment that are among the main complaints of patients seeking TMD treatment—pain level and chewing ability—and changes in the KG assessment of jaw motion. Our main purpose was to assess how the expected decrease in pain level and increase in chewing ability after treatment related to changes in jaw-movement speed and mouth-opening patterns, thereby evaluating the usefulness of jaw KG in monitoring treatment effectiveness across time. To address this clinical research question, we adopted a treatment protocol involving a cycle of five weekly arthrocentesis procedures with the addition of hyaluronic acid injections to maximize positive outcomes. Such a protocol has been shown to be effective in reducing symptoms of TMJ osteoarthritis even in the long term.[12] Despite concerns about potential overtreatment related to its adoption that recently have led to the design of studies aimed at defining less invasive protocols,[14] we should point out that the goal of our investigation was to monitor KG changes after treatment with respect to the expected decrease in pain and increase in chewing ability. The underlying premise of this investigation was that a correlation between the treatment-related changes in clinical and KG parameters, if it existed, should be independent of the treatment approach.

At baseline, we observed only a weak correlation between pain levels and average jaw-opening speed. After treatment, a substantial majority of participants reported improvement at the end of the treatment period in subjective chewing ability (82.3 percent) and pain level (76.4 percent). With the exception of deviations from the midsagittal plane, improvement in the KG parameters assessing jaw-movement speed were reported by at least one-half of the participants (range, 50.0-61.7 percent). Notwithstanding that, improvement in the clinical parameters was more marked than that in the KG variables. We recorded an average improvement of 41 percent in pain level ($P = .002$) and of 27 percent in chewing ability ($P = .005$), whereas none of the KG parameters showed changes higher than 15 percent with respect to baseline values ($P > .05$). The most important finding was that changes in pain level and chewing ability were not correlated with any of the KG variables. Also, neither pain nor chewing ability levels were correlated with any of the assessed KG parameters at the end of the treatment period. These observations have important clinical implications, because they mean that the hypothesis that KG parameters are correlated with clinical symptoms has to be rejected. So, findings from this investigation suggested that jaw-tracking devices cannot detect variations in the primary pain-related outcome variables. The clinical research question underlying this investigation—"Does a treatment-related change in pain levels and chewing ability coincide with a change in any KG parameters?"—has to be answered "no."

In clinical terms, this means that KG recordings of jaw movement are not useful in monitoring the course of pain symptoms or subjective limitations in chewing ability, which likely are the two main reasons patients seek treatment. Also, interestingly, the patients' average maximum jaw speed during opening and closing movement at the end of the treatment period was about 140 to 145 mm/second, which is a value far below the minimum threshold for maximum velocity (250 mm/second) assumed as a physiological parameter by a panel of KG experts.[8] We observed a similar finding with values of maximum speed at terminal closure, which were about 36 mm/second on average

TABLE 2

Significance of changes in the study variables across time.

PARAMETER	EXPECTED IMPROVEMENT*	BASELINE SCORE (STANDARD DEVIATION)	END-OF-TREATMENT SCORE (STANDARD DEVIATION)	*P* VALUE (SIGNIFICANCE OF CHANGES)
Chewing Ability (0-10)†	+	6.3 (1.5)	8.0 (1.5)	.005‡
Pain Level (0-10)§	–	5.6 (2.6)	3.3 (2.9)	.002†
Mouth Opening (Millimeters)	+	35.0 (6.4)	36.1 (6.4)	.482
Maximum Left Deviation (mm)	–	2.3 (2.0)	3.1 (2.6)	.162
Maximum Right Deviation (mm)	–	2.3 (1.8)	2.2 (2.6)	.966
Maximum Jaw-Opening Speed (mm/Second)	+	125.5 (69.7)	140.1 (76.6)	.415
Average Jaw-Opening Speed (mm/Second)	+	68.7 (42.9)	71.8 (40.5)	.761
Maximum Jaw-Closing Speed (mm/Second)	+	132.5 (71.1)	145.3 (87.7)	.508
Average Jaw-Closing Speed (mm/Second)	+	78.8 (48.4)	84.6 (58.7)	.658
Maximum Speed at Teeth-Contact Point (mm/Second)	+	30.4 (34.9)	36.1 (39.0)	.528

* A plus sign indicates an increase in score on the visual analog scale (VAS) being used for the parameter; a minus sign indicates a decrease.
† Assessed by means of a VAS that ranged from 0 (eating only semiliquid food) to 10 (eating solid hard food).
‡ Significant at $P < .01$.
§ Assessed by means of a VAS that ranged from 0 (no pain) to 10 (pain as bad as the patient ever experienced).

with respect to a purported optimal value of 100 mm/second. Only four of 34 participants (11.8 percent) surpassed the minimum thresholds for maximum jaw speed during movement, and no participants reached the minimum threshold for maximum jaw speed at terminal closure. This means that although it was not possible to assess the diagnostic accuracy of jaw-speed parameters in this study owing to the absence of asymptomatic control participants, it can be suggested that overdiagnosis problems are a matter of fact if TMD diagnosis relies on KG parameters alone. Studies involving larger samples, possibly with the inclusion of populations with other TMDs (such as myofascial pain) and of untreated control participants, are recommended to integrate knowledge regarding the accuracy of jaw-motion recordings and their possible natural fluctuation.

These findings are in line with the suggestions from several reviews claiming that the available technological devices, although they purportedly try to perform objective recordings of the clinical pictures, are not able to discriminate between patients with and without TMD pain.[4,9,18-21] In addition, our findings add data regarding these devices' lack of usefulness in monitoring disease. Notwithstanding the negative evidence coming from the re-

TABLE 3

Changes from baseline levels to end-of-treatment levels in all the outcome parameters: data for individual patients.

PATIENT	CHEWING ABILITY (0-10)*	PAIN LEVEL (0-10)†	MOUTH OPENING (MILLIMETERS)	MAXIMUM DEVIATION (mm)	
				Left	Right
Expected Change	+	–	+	–	–
Patient 1	+3	−3	+3.4	+0.4	+5.9
Patient 2	+1	−3	+8.8	−2.4	+6.4
Patient 3	+3	−1	−0.3	+6.1	+0.2
Patient 4	+1	−6	+1.6	−0.8	No change
Patient 5	+4	−1	+4.0	+4.8	−2.9
Patient 6	+1	−5	−8.5	+0.1	+1.0
Patient 7	+2	−3	−0.8	−0.4	+0.6
Patient 8	−1	No change	+2.3	+0.3	No change
Patient 9	+3	−5	+3.3	−2.1	−1.5
Patient 10	+1	−8	+1.3	+1.1	−4.7
Patient 11	+2	No change	+2.4	+4.2	−0.5
Patient 12	+1	−1	−4.7	+2.2	−2.0
Patient 13	+3	−4	+0.4	+0.7	−1.6
Patient 14	+1	No change	−2.3	−1.6	+5.5
Patient 15	+5	+4	+4.8	+6.2	−1.1
Patient 16	+3	−9	+5.5	+1.6	+0.2
Patient 17	+1	−3	+0.2	+3.3	−2.4
Patient 18	+2	−2	−5.7	+4.3	−3.8
Patient 19	−2	No change	−4.8	−0.6	+0.5
Patient 20	+3	+1	+2.4	No change	+0.3
Patient 21	+2	−5	+1.3	−0.1	+0.1
Patient 22	+3	−3	−2.0	+0.6	No change
Patient 23	+3	−1	+7.8	−1.8	+1.1
Patient 24	−1	+1	+0.4	+0.7	−1.0
Patient 25	+2	−4	+1.0	−0.2	−0.7
Patient 26	−4	−4	−6.5	−1.1	−1.6
Patient 27	+2	−7	+0.4	−0.9	+1.3
Patient 28	+3	−1	+7.0	+5.8	−1.1
Patient 29	+1	−4	+2.9	−2.9	+1.2
Patient 30	+5	−2	+3.3	−0.1	+1.0
Patient 31	+4	−4	+4.0	−0.8	+1.6
Patient 32	No change	−1	+2.3	−0.6	−1.4
Patient 33	−1	−1	−2.9	−0.2	−0.6
Patient 34	+1	−1	+5.2	+1.6	−0.8

* Assessed by means of a visual analog scale (VAS) that ranged from 0 (eating only semiliquid food) to 10 (eating solid hard food). A plus sign indicates an increase in score on the VAS; a minus sign indicates a decrease.

† Assessed by means of a VAS that ranged from 0 (no pain) to 10 (pain as bad as the patient ever experienced). A plus sign indicates an increase in score on the VAS; a minus sign indicates a decrease.

TABLE 3 (CONTINUED)

JAW-OPENING SPEED (mm/SECOND)		JAW-CLOSING SPEED (mm/SECOND)		MAXIMUM SPEED AT TEETH-CONTACT POINT (mm/SECOND)
Maximum	Average	Maximum	Average	
+	+	+	+	+
+1.3	−11.6	+11.2	+3.1	−30.2
+13.7	+10.9	+10.0	+11.9	+15.4
+13.7	−12.8	−6.3	+0.1	+3.5
−38.8	+9.8	−88.7	−61.0	−10.6
+32.5	+14.9	−11.3	−2.2	+17.0
+5.0	+29.7	+103.3	+46.4	+35.3
+8.7	+19.6	+70.0	+55.0	+12.1
+128.7	+57.4	+47.5	+24.1	−4.9
+43.7	+29.8	+46.2	+31.4	+6.5
−12.5	−41.2	−11.2	+7.1	−1.0
−95.0	−58.6	−73.7	−56.0	−9.3
+20.0	+17.3	+11.3	−1.2	−4.4
+76.3	+47.8	−7.5	+7.2	−6.3
+91.2	+61.8	+83.8	+64.8	+5.4
−17.5	−17.0	+85.0	+35.2	−7.5
−3.7	+6.4	+12.5	+8.2	+13.7
+12.5	+21.6	+82.5	+77.1	+93.5
−18.8	−18.8	−70.0	−36.3	−19.2
+248.7	−3.9	+90.0	−71.7	−13.2
+76.2	+55.7	+18.7	+18.6	+2.2
−30.0	−0.7	−41.2	+6.9	+87.6
−42.5	−34.0	−7.5	−0.4	+4.4
−131.3	−92.2	−27.5	−56.7	−16.9
−6.3	−5.7	+42.5	+20.3	+7.5
−2.5	+2.6	−18.7	−23.6	−18.9
−30.0	−19.2	−107.5	−73.9	No change
+96.3	+51.4	+37.5	+27.8	+7.0
+47.5	+26.0	+11.2	+2.4	+38.3
+25.0	+18.6	+80.0	+47.7	+10.4
+3.8	−5.7	+20.0	−4.3	−46.4
−67.5	−62.5	+51.3	+59.1	+23.8
+11.2	−5.5	−85.0	−32.0	+4.7
−3.8	+16.1	−12.5	+2.7	−14.6
+40.0	+4.3	+9.5	+59.0	+10.0

search setting, such instruments still seem to be used widely among clinical practitioners, and in recent years, studies of commercially available devices have been designed to determine how accurately the instruments detect clinical symptoms.[10,11] Investigations regarding postural platforms and electromyographic recordings have failed to support these devices' usefulness in the clinical setting,[10,22,23] but at the time of our study, no studies were available regarding jaw-tracking devices. In a study of hyaluronic acid injections in the TMJ, investigators found that the KG parameters—as measured according to empirically drawn criteria describing three types of jaw-opening and -closing trajectories—improved after treatment.[24] In any case, one must keep in mind that changes in jaw-motion trajectories cannot be considered markers of treatment effectiveness unless it is proven that a certain KG finding is a reliable diagnostic marker.

Our findings suggest that changes in jaw speed are not significantly correlated with changes in pain symptoms and cannot be considered an indicator for disease—and, therefore, do not support the use of jaw-tracking devices to monitor treatment effectiveness of TMJ osteoarthritis in the clinical setting. Nonetheless, it is noteworthy that an increase in speed during jaw movements, even if it is not significant, was demonstrated in most participants in our study. Such findings are not unexpected, because they are in line with the pain adaptation model and its integrations, which postulate that pain leads to alterations in muscle activity that limit movement and, thereby, protect the musculoskeletal system from further injury.[25,26] These observations suggested that, independently of the absolute magnitude of the value of instrumental parameters, commercially available devices are able to replicate findings achieved in laboratory settings regarding the pain–motor activity relationship, as already shown in a recent EMG study.[10]

The potential importance of these findings needs to be considered in future research aimed at refining—if they exist—the real indications for using these devices for clinical purposes. Also, the KG parameters we investigated and their recorded measures might reflect some aspects of jaw movement not influenced by the injection of hyaluronic acid directly into the joint space, which did not change the basic osteoarthritic-induced joint pathology although it made a significant difference in reported pain and improved ability to move the jaw for chewing. On the other hand,

TABLE 4

Permutation test: correlation levels (*P* values) between treatment-related changes in kinesiographic and clinical parameters.

KINESIOGRAPHIC PARAMETER	CORRELATION BETWEEN OUTCOMES (*P*)	
	Chewing Ability	Pain Level
Mouth Opening (Millimeters)	0.388 (.02)*	0.011 (.94)
Maximum Left Deviation (mm)	0.366 (.03)*	0.358 (.03)*
Maximum Right Deviation (mm)	0.003 (.98)	–0.046 (.79)
Maximum Jaw-Opening Speed (mm/Second)	–0.245 (.16)	0.079 (.65)
Average Jaw-Opening Speed (mm/Second)	–0.218 (.21)	–0.150 (.39)
Maximum Jaw-Closing Speed (mm/Second)	0.034 (.84)	0.264 (.13)
Average Jaw-Closing Speed (mm/Second)	0.199 (.25)	0.044 (.80)
Maximum Speed at Teeth-Contact Point (mm/Second)	0.287 (.09)	–0.154 (.38)

* Significant at $P < .05$.

TABLE 5

Single-variable correlation analysis: correlation levels (*P* values) between kinesiographic and clinical parameters at the end of the treatment period.

KINESIOGRAPHIC PARAMETER	CORRELATION WITH END-OF-TREATMENT VALUE (*P*)	
	Chewing Ability	Pain Level
Mouth Opening (Millimeters)	–0.017 (.92)	0.084 (.63)
Maximum Left Deviation (mm)	0.079 (.65)	0.119 (.50)
Maximum Right Deviation (mm)	0.136 (.44)	0.175 (.32)
Maximum Jaw-Opening Speed (Millimeters/Second)	0.086 (.62)	–0.085 (.63)
Average Jaw-Opening Speed (mm/Second)	0.205 (.24)	–0.199 (.26)
Maximum Jaw-Closing Speed (mm/Second)	0.107 (.54)	–0.163 (.35)
Average Jaw-Closing Speed (mm/Second)	0.175 (.32)	–0.241 (.17)
Maximum Speed at Teeth-Contact Point (mm/Second)	0.062 (.72)	–0.299 (.18)

we should point out that it is the duty of the manufacturers and the accustomed users to propose well-defined indications for the use of technological devices in patients with TMD to prevent their misuse in clinical and research settings.

As a recommendation for future studies, we believe efforts must be made in the research setting to try to correlate instrumental signs with clinical symptoms to implement knowledge and provide evidence-based data about the clinical significance of any specific instrumental findings. Our study's small sample size and the lack of random selection of participants—even if understandable owing to the features of the studied condition and the adopted treatment—are potential shortcomings to be addressed in future research. However, even if the statistical significance of the changes in KG findings may be reappraised in studies involving larger samples, the clinical significance of those changes is unrelated to the sample size because, to achieve clinical significance, improvement in a treatment outcome parameter should be much higher than that demonstrated for KG variables in our investigation. Also, on the basis of this study's rationale, it is not likely that our findings reporting that absence of correlation were influenced by the particular treatment approach we used, even if investigations of other treatment approaches and other TMD populations are recommended to confirm these results. In any case, according to the current concepts of TMDs, technological devices are able to provide, at best, ancillary findings to the clinical assessment and cannot be proposed as stand-alone instruments to diagnose or monitor the disease.[18,20,21]

CONCLUSIONS

We performed our study to test the hypothesis that treatment-related changes in KG parameters of jaw speed and mouth opening were correlated with changes in pain level and chewing ability, in an attempt to assess the usefulness of jaw-tracking devices to monitor the disease. None of the KG parameters we investigated was able to indicate changes in the primary pain-related outcome variables in patients with TMJ osteoarthritis during the cycle of five weekly arthrocentesis procedures with hyaluronic acid injections. These findings suggested that jaw KG is not useful in monitoring the disease in the clinical setting, if pain variables are assumed to be the primary outcome measures. ■

Disclosure. None of the authors reported any disclosures.

The authors thank Dr. Stefano Tonello, School of Dentistry, University of Padova, Italy, for his useful suggestions and help in assessing kinesiographic recordings.

1. Laskin DM. Etiology of the pain-dysfunction syndrome. JADA 1969;79(1):147-153.
2. Greene CS. The etiology of temporomandibular disorders: implications for treatment. J Orofac Pain 2001;15(2):93-105.
3. Manfredini D. Fundamentals of TMD management. In: Manfredini D, ed. Current Concepts on Temporomandibular Disorders. London: Quintessence; 2010:305-318.
4. Baba K, Tsukiyama Y, Yamazaki M, Clark GT. A review of temporomandibular disorder diagnostic techniques. J Prosthet Dent 2001;86(2):184-194.
5. Greene CS. The role of biotechnology in TMD diagnosis. In: Laskin DM, Greene CS, Hylander WL, eds. Temporomandibular Disorders: An Evidence-Based Approach to Diagnosis and Treatment. Chicago: Quintessence; 2006:193-202.
6. Gonzalez YM, Greene CS, Mohl ND. Technological devices in the diagnosis of temporomandibular disorders. Oral Maxillofac Surg Clin North Am 2008;20(2):211-220.
7. Jankelson B, Swain CW, Crane PF, Radke JC. Kinesiometric instrumentation: a new technology. JADA 1975;90(4):834-840.
8. Cooper BC. Parameters of an optimal physiological state of the masticatory system: the results of a survey of practitioners using computerized measurement devices. Cranio 2004;22(3):220-233.
9. Lund JP, Widmer CG, Feine JS. Validity of diagnostic and monitoring tests used for temporomandibular disorders. J Dent Res 1995; 74(4):1133-1143.
10. Manfredini D, Cocilovo F, Favero L, Ferronato G, Tonello S, Guarda-Nardini L. Surface electromyography of jaw muscles and kinesiographic recordings: diagnostic accuracy for myofascial pain (published online ahead of print April 11, 2011). J Oral Rehabil 2011; 38(11):791-799. doi:10.1111/j.1365-2842.2011.02218.x.
11. Manfredini D, Favero L, Federzoni E, Cocilovo F, Guarda-Nardini L. Kinesiographic recordings of jaw movements are not accurate to detect magnetic resonance–diagnosed temporomandibular joint (TMJ) effusion and disk displacement: findings from a validation study. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;114(4): 457-463.
12. Guarda-Nardini L, Stifano M, Brombin C, Salmaso L, Manfredini D. A one-year case series of arthrocentesis with hyaluronic acid injections for temporomandibular joint osteoarthritis (published online ahead of print April 6, 2007). Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103(6):e14-e22. doi:10.1016/j.tripleo.2006.12.021.
13. Manfredini D, Bonnini S, Arboretti R, Guarda-Nardini L. Temporomandibular joint osteoarthritis: an open label trial of 76 patients treated with arthrocentesis plus hyaluronic acid injections (published online ahead of print April 29, 2009). Int J Oral Maxillofac Surg 2009;38(8):827-834. doi:10.1016/j.ijom.2009.03.715.
14. Manfredini D, Rancitelli D, Ferronato G, Guarda-Nardini L. Arthrocentesis with or without additional drugs in temporomandibular joint inflammatory-degenerative disease: comparison of six treatment protocols (published online ahead of print Oct. 15, 2011). J Oral Rehabil 2012;39(4):245-251. doi:10.1111/j.1365-2842.2011.02265.x.
15. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. J Craniomandib Disord 1992;6(4):301-355.
16. Stohler CS, Zarb GA. On the management of temporomandibular disorders: a plea for a low-tech, high-prudence therapeutic approach. J Orofac Pain 1999;13(4):255-261.
17. Manfredini D, Bucci MB, Montagna F, Guarda-Nardini L. Temporomandibular disorders assessment: medicolegal considerations in the evidence-based era (published online ahead of print Aug. 19, 2010). J Oral Rehabil 2011;38(2):101-119. doi:10.1111/j.1365-2842.2010.02131.x.
18. Klasser GD, Okeson JP. The clinical usefulness of surface electromyography in the diagnosis and treatment of temporomandibular disorders. JADA 2006;137(6):763-771.
19. Suvinen TI, Kemppainen P. Review of clinical EMG studies related to muscle and occlusal factors in healthy and TMD subjects. J Oral Rehabil 2007;34(9):631-644.
20. Perinetti G, Contardo L. Posturography as a diagnostic aid in dentistry: a systematic review (published online ahead of print Oct. 29, 2009). J Oral Rehabil 2009;36(12):922-936. doi:10.1111/j.1365-2842.2009.02019.x.
21. Baba K, Ono Y, Clark GT. Instrumental approach. In: Manfredini D, ed. Current Concepts on Temporomandibular Disorders. London: Quintessence; 2010:223-236.
22. Perinetti G. Temporomandibular disorders do not correlate with detectable alterations in body posture. J Contemp Dent Pract 2007;8(5):60-67.
23. Hellmann D, Giannakopoulos NN, Blaser R, Eberhard L, Schindler HJ. The effect of various jaw motor tasks on body sway (published online ahead of print March 9, 2011). J Oral Rehabil 2011;38(10):729-736. doi:10.1111/j.1365-2842.2011.02211.x.
24. Sato S, Nasu F, Motegi K. Analysis of kinesiograph recordings and masticatory efficiency after treatment of non-reducing disk displacement of the temporomandibular joint. J Oral Rehabil 2003; 30(7):708-713.
25. Lund JP, Donga R, Widmer CG, Stohler CS. The pain-adaptation model: a discussion of the relationship between chronic musculoskeletal pain and motor activity. Can J Physiol Pharmacol 1991;69(5):683-694.
26. Murray GM, Peck CC. Orofacial pain and jaw muscle activity: a new model. J Orofac Pain 2007;21(4):263-278.