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Use of the Krogh-Poulsen Test, Cone-Beam Computed Tomography, and Surface Electromyography in Distinguishing Muscular From Articular Temporomandibular Disorders

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Abstract

Objectives

The objective of this study is to assess whether the Krogh-Poulsen bite test agrees with cone-beam computed tomography (CBCT) and surface electromyography (sEMG) in distinguishing muscular from articular temporomandibular disorders (TMD).

Materials and methods

This prospective study included 88 consecutive adults with TMD seen between 1 June 2019 and 30 March 2022. Each side was classified as muscular or articular with the bite test. Condylar changes were graded on CBCT with the Koyama classification, and masseter and anterior temporalis activity was recorded at rest and in maximum intercuspation (MI). Condylar types were compared with an exact permutation chi-square test, sEMG parameters with Student's t-test, and one-way analysis of variance (ANOVA).

Results

The mean age was 32.2 ± 10.1 years, and 55 of the 88 patients (62.5%) were men. The bite test was positive on 55 right sides (62.5%) and 63 left sides (71.6%). On the right, no muscular side (0/29, 0.0%) showed erosion or deformation, compared with 14 of 26 articular sides (53.8%) ($\chi^2(4) = 21.7$, exact $p < 0.0001$, and Cramér's $V = 0.63$). On the left, the corresponding figures were three of 27 (11.1%) and 21 of 36 (58.3%) ($\chi^2(4) = 18.7$, exact $p < 0.001$, and $V = 0.54$). Resting sEMG did not differ between groups. In MI, temporalis amplitude was higher on muscular sides (198.0 versus 161.2 µV; $t(116) = 2.20$, $p = 0.030$, and $d = 0.41$), whereas masseter firing rate was higher on articular sides (28.7 versus 21.1 Hz; $t(116) = -3.59$, $p < 0.001$, and $d = -0.66$). On the left, masseter amplitude in MI varied with condylar morphology ($F(4, 58) = 3.53$, $p = 0.012$, and $\eta^2 = 0.20$).

Conclusions

The Krogh-Poulsen test separated muscular from articular disorders in a way largely confirmed by imaging and electromyography. It may help to orient the indication for tomography, but because CBCT and sEMG were performed only on sides with a positive test, its use as a first-line triage tool requires validation against an appropriate diagnostic reference standard before it can be recommended in routine practice.

Categories: Neurology, Radiology, Dentistry
Keywords: cone-beam computed tomography, diagnosis, electromyography, mandibular condyle, masticatory muscles, temporomandibular joint disorders

Introduction

Temporomandibular disorders (TMD) are the leading non-dental cause of orofacial pain. A recent meta-analysis estimated that close to a third of adults meet the diagnostic criteria [1], with marked differences according to age and sex [2]. Because most patients are young adults in active employment, diagnostic delay and inappropriate treatment carry a real personal and economic cost.

Validated classifications are available. The Research Diagnostic Criteria (RDC/TMD), replaced in 2014 by the Diagnostic Criteria for TMD (DC/TMD), provides a standardized framework for research and clinical practice [3,4]. In everyday consultations, however, preauricular pain may arise from the masticatory muscles, from the joint itself, or from both, and history and palpation do not always allow the clinician to decide [5]. The distinction has practical weight, since myogenous and arthrogenous disorders are not managed in the same way.

The posterior bite test described by Krogh-Poulsen is among the oldest chairside tools proposed for this purpose [6]. The patient bites firmly on a thin, rigid wooden spatula placed between the molars on one side. Pain felt on the same side is interpreted as muscular, whereas pain on the opposite side points to the joint. The test takes less than a minute and requires no equipment. Its clinical value has nevertheless been examined in only a few studies, and we found little work comparing it with objective imaging or functional recordings [7].

Cone-beam computed tomography (CBCT) has become the reference examination for the osseous components of the temporomandibular joint (TMJ), at a radiation dose well below that of medical CT [8]. It shows flattening, erosion, osteophytes, and changes in joint space that are often missed on panoramic radiographs [9-12]. Surface electromyography (sEMG), for its part, quantifies the activity of the masticatory muscles at rest and during clenching. Its diagnostic role in TMD is still debated [13], although several studies have reported differences in masseter and temporalis activity between patients and controls [14,15].

The two examinations are complementary: CBCT describes the structure of the bony joint but gives no information on muscle function, whereas sEMG describes how the masticatory muscles work but shows nothing of the joint. Since TMD may involve the muscles, the joint, or both, combining a structural and a functional assessment may help to understand what a muscular or articular response to a clinical test actually reflects.

To our knowledge, these three tools have not previously been compared in the same group of patients. The aim of this study was therefore to assess the agreement between the Krogh-Poulsen test, CBCT, and sEMG in adults with TMD and to consider whether the bite test could serve as a simple first-line filter before more costly investigations.

Materials And Methods

Study design and setting

This was a prospective descriptive study carried out in the Department of Dental Medicine of the Central Hospital of the Army, Algiers, with the radiology and neurology departments of the same hospital. Patients were recruited from 1 June 2019 to 30 March 2022. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for observational studies [16].

Participants

Adults aged 18 years or more were enrolled in the order in which they appeared in the consultation register. To be included, they had to show at least one sign of TMD (pain, limited mouth opening, joint sounds, catching, or subluxation), have a satisfactory dentition with stable bilateral molar support, and open the mouth by at least 20 mm. We excluded patients previously treated for TMD and those with a known rheumatic disease, unclear pain type, a history of TMJ fracture or surgery, a malignant tumor of the upper aerodigestive tract, an active cervicofacial infection, or pain related to third molar eruption.

The sample size was calculated with the formula for estimating a single proportion, given in Equation 1 [17]:

$$n = \frac{Z^2_{1-\alpha/2}\, p\,(1-p)}{d^2} (1)$$

where n is the minimum number of patients, Z is the standard normal deviate for a two-sided alpha risk of 5% (Z = 1.96), p is the expected proportion, and d is the absolute precision. We assumed a TMD prevalence of 5% in adults (p = 0.05), in line with the 4.6% prevalence of TMD-type pain reported in that national population survey, and an absolute precision of 5% (d = 0.05) [18]. Substituting these values gives Equation 2:

$$n = \frac{1.96^2 \times 0.05 \times (1-0.05)}{0.05^2} = 72.99 \approx 73 (2)$$

The minimum sample size was therefore 73 patients. To allow for refusals and unusable recordings, we added an expected loss of about 10% of this number (about eight patients), as shown in Equation 3:

$$n_{\text{adj}} = 73 \times (1 + 0.10) = 80.3 \approx 81 (3)$$

We therefore planned to recruit at least 81 patients, and 88 were finally included.

Clinical examination and Krogh-Poulsen test

One examiner took the history and performed a standard extraoral and intraoral examination, and the clinical signs were recorded following the DC/TMD examination protocol and definitions [3]. The DC/TMD protocol and its examination forms are freely available (open access) from the International Network for Orofacial Pain and Related Disorders Methodology (INfORM) website (https://ubwp.buffalo.edu/rdc-tmdinternational/). Mouth opening was measured in millimeters, and joint sounds were recorded with a stethoscope and classed as click, coarse crepitus, or fine crepitus. Masseter and temporalis were palpated as recommended by the DC/TMD, first lightly and then with firm pressure, looking for pain, hypertrophy, and trigger points. Pain intensity was rated by the patient on a 10 cm visual analogue scale (VAS) from 0 (no pain) to 10 (worst imaginable pain). The graphic rating scale was originally developed by Hayes and Patterson [19] and was adapted to the measurement of pain by Huskisson [20]. The VAS is a nonproprietary, open-access instrument in the public domain, so no permission was required for its use; the DC/TMD protocol and forms are likewise open access, and no other questionnaire, score, or proprietary instrument was used in this study. All patients with pain scored between 2 and 8, and scores were grouped by the investigators as mild (2-4), moderate (5-6), and severe (7-8). Pain persisting for three months or longer was recorded as chronic, in line with the International Association for the Study of Pain (IASP) definition [21].

For the Krogh-Poulsen test, the patient bit firmly on a thin wooden tongue depressor placed between the molars of one side, and the test was then repeated on the other side [6,7]. The same type of spatula was used for every patient. Pain on the biting side was scored as muscular, pain on the opposite side as articular, and the absence of pain as negative. When both responses were present, the patient was considered mixed. For the side-by-side analysis, each side of a mixed patient was assigned to the group matching its own response.

The test followed the same protocol for every patient: It was performed by the same examiner at the first clinical examination, with the same type of spatula, the same instruction to bite firmly, and the same order of testing, and the response was classified according to the side on which the patient reported pain. Biting force was not measured, so it was standardized only by the instruction given, and the reproducibility of the test was not assessed with a second examiner. Because CBCT was requested on the basis of the bite test result, the test was always performed and interpreted before imaging, so the examiner was unaware of the CBCT findings at that stage. However, the same clinician later took part in reading the scans and was then aware of the bite test result.

Cone-beam CT

All scans were made on the same unit (Orthophos XG 3D, Sirona Dental Systems, Bensheim, Germany) in TMJ mode, with the patient standing and the head stabilized, at 85 kV and 13 mA. Images were exported in Digital Imaging and Communications in Medicine (DICOM) format and read in Sidexis 4 (Dentsply Sirona, Bensheim, Germany) in axial, coronal, and corrected sagittal planes. Each condyle was graded with the classification of Koyama et al. [9]: type N, normal contour; type F, flattening of the anterosuperior or posterosuperior surface; type E, erosion or partial hypodense change, with or without a rough cortex; type D, deformation such as a beak, without erosion; and type S, deformation combined with erosion. Joint space and the glenoid fossa were graded as positive, negative, or mixed, following the RDC/TMD image analysis criteria of Ahmad et al. [10]. All scans were read by the same radiologist together with the first author.

Surface electromyography

Recordings were made in the neurology department on a four-channel Neuropack system (Nihon Kohden, Tokyo, Japan). The skin was cleaned with alcohol, a ground electrode was placed on the forearm, and the head was oriented to the Frankfort plane in a quiet room. For each muscle, two surface electrodes were placed 20 mm apart along the fibers, following the SENIAM recommendations and anatomical landmarks measured from the tragus-infraorbital line [22]. Signals were band-pass filtered between 10 and 100 Hz.

Right and left masseter and anterior temporalis were recorded at rest (freeway space of 1-3 mm) and in maximum intercuspation (MI). Each recording lasted five seconds and was repeated three times, and the mean of the three trials was kept. The EMG2 software (Nihon Kohden, Tokyo, Japan) rectified and smoothed the signal and returned the root mean square amplitude (µV), the motor unit firing rate (Hz), and the rise parameter of the motor unit potentials ("Rise," in the units of the software). Amplitudes were not normalized, because both tasks are isometric and the same gain was used for every patient.

Statistical analysis

Data were entered in EpiData Entry 3.0 (EpiData Association, Odense, Denmark), checked in Epi Info 6.04 (CDC, Atlanta, GA), and analyzed in EpiData Analysis 2.2. Quantitative data are given as mean ± standard deviation (SD) for patient characteristics and mean ± standard error (SE) for sEMG parameters and qualitative data as n (%). The side was the unit of analysis for the bite test, CBCT, and sEMG. Condylar types (five categories) were compared between muscular and articular sides with an exact permutation version of Pearson's chi-square test [23,24] (100,000 resamples), because several cells held fewer than five joints, and Cramér's V is given as the effect size [25].

sEMG parameters were compared between muscular and articular sides with Student's t-test for independent samples [26], with Cohen's d as the effect size [27], and between condylar types with one-way analysis of variance (ANOVA) [28], with eta squared (η^2) as the effect size [27]. When the ANOVA was significant, pairwise comparisons were made with Bonferroni correction for the 10 possible pairs [29]. For full reporting, test statistics, degrees of freedom, and effect sizes were recalculated in Python (SciPy) (Python Software Foundation, Fredericksburg, VA) from the group means, standard errors, and sample sizes recorded in the study database [30]; the exact permutation tests were also run in Python. Because the right and left sides of the same patient could both contribute observations, the observations are not fully independent, and this within-patient correlation may lead to underestimated standard errors and p values that are somewhat too small. The CBCT comparisons were therefore made separately for each side so that each patient contributed only one observation per analysis, whereas the pooled sEMG comparisons between muscular and articular sides include both sides of some patients and should be interpreted with this in mind. A p value below 0.05 was considered significant.

Ethics

The study was conducted as part of a doctoral thesis at the Faculty of Medicine of the University of Algiers 1, with the agreement of the departments of dental medicine, radiology, and neurology of the Central Hospital of the Army. The protocol was approved by the Scientific Council of the Faculty of Medicine of the University of Algiers 1 (decision number 25, dated 28 May 2019), and the study followed the principles of the Declaration of Helsinki. Every patient was informed of the aims of the study and signed a written consent form allowing the use of his or her clinical record for research.

Results

Patients

Eighty-eight patients were included: 55 men (62.5%) and 33 women (37.5%). Their mean age was 32.2 ± 10.1 years (range: 18-70), and 58 of 88 (65.9%) were between 20 and 39 years old. Pain was the main reason for consulting in 51 patients (58.0%), followed by joint sounds in 24 (27.3%) and referral from another department in 23 (26.1%). Mean pain-free opening was 37.6 ± 7.6 mm, and mean assisted maximum opening was 45.6 ± 7.1 mm. Table *1* summarizes the clinical profile.

Characteristic	Category	N	n	%
Sex	Men	88	55	62.5
	Women	88	33	37.5
Age group	20-39 years	88	58	65.9
	Outside 20-39 years	88	30	34.1
Pain	Present	88	77	87.5
	Absent	88	11	12.5
Pain duration	Chronic	77	47	61.0
	Acute	77	30	39.0
Pain intensity on VAS	Mild (2-4)	77	35	45.5
	Moderate (5-6)	77	25	32.5
	Severe (7-8)	77	17	22.1
Pain trigger	Chewing	77	30	39.0
Associated symptom	Headache	88	15	17.0
Mandibular movement	Altered opening path	88	38	43.2
Palpation	Muscle pain	88	36	40.9
Joint sounds on opening	Right side	88	33	37.5
	Left side	88	34	38.6
Occlusion	Occlusal interferences	88	39	44.3
Final diagnosis	Muscular	88	40	45.5
	Articular	88	39	44.3
	Mixed	88	9	10.2

TABLE 1: Clinical characteristics of the 88 patients

N is the denominator used for each percentage: all 88 patients or the 77 patients with pain for pain duration, pain intensity, and pain trigger. Outside 20-39 years: patients aged 18-19 years or 40 years and over. Altered opening path: deviation or deflection of the mandible on opening. Chronic pain: pain persisting for three months or longer

VAS: visual analogue scale

Krogh-Poulsen test and CBCT findings

The bite test was positive on 55 of 88 right sides (62.5%) and 63 of 88 left sides (71.6%). On the right, muscular and articular responses were almost balanced, whereas on the left, articular responses were more frequent (Table *2*). CBCT was performed on every side with a positive test, that is, 55 right and 63 left joints. Normal and flattened condyles were the most common findings on both sides.

Finding	Right, n (%)	Left, n (%)
Krogh-Poulsen negative	33 (37.5)	25 (28.4)
Krogh-Poulsen muscular	29 (33.0)	27 (30.7)
Krogh-Poulsen articular	26 (29.5)	36 (40.9)
Condyle type N (normal)	25 (28.4)	26 (29.5)
Condyle type F (flattening)	16 (18.2)	13 (14.8)
Condyle type E (erosion)	5 (5.7)	9 (10.2)
Condyle type D (deformation)	4 (4.5)	10 (11.4)
Condyle type S (deformation and erosion)	5 (5.7)	5 (5.7)
CBCT not indicated (negative test)	33 (37.5)	25 (28.4)

TABLE 2: Krogh-Poulsen responses and CBCT condylar morphology by side (n = 88 patients)

Condylar types follow the classification of Koyama et al. [9]

CBCT: cone-beam computed tomography

CBCT findings were consistent with the bite test (Table *3* and Figure *1*). On the right, every condyle on a muscular side was either normal (19/29, 65.5%) or flattened (10/29, 34.5%), whereas 14 of the 26 articular sides (53.8%) showed erosion, deformation, or both ($\chi^2(4) = 21.7$, exact $p < 0.0001$, and Cramér's $V = 0.63$). The left side followed the same pattern: 24 of 27 muscular sides (88.9%) had a type N or F condyle, against 15 of 36 articular sides (41.7%), and type D was seen only on articular sides (10/36, 27.8%) ($\chi^2(4) = 18.7$, exact $p < 0.001$, and $V = 0.54$).

Side	Muscular sides with type E, D, or S, n (%)	Articular sides with type E, D, or S, n (%)	χ^2 (df = 4)	Exact p	Cramér's V
Right	0/29 (0.0)	14/26 (53.8)	21.7	<0.0001	0.63
Left	3/27 (11.1)	21/36 (58.3)	18.7	<0.001	0.54

TABLE 3: Condylar erosion or deformation on CBCT according to the Krogh-Poulsen response

The test is an exact permutation chi-square test (100,000 resamples) comparing the full distribution of the five condylar types (N, F, E, D, and S) between muscular and articular sides; the complete counts are shown in Figure 1

df, degrees of freedom; E, erosion; D, deformation; S, deformation and erosion; N, normal; F, flattening

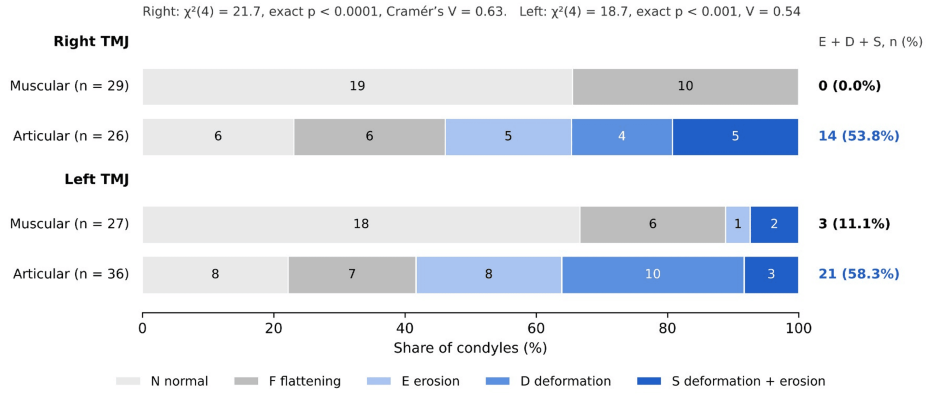


FIGURE 1: Condylar morphology on CBCT according to the Krogh-Poulsen response

Each bar shows the number of condyles of each type, and the value on the right gives the number (%) of altered condyles (types E, D, and S) in each group. Right side: muscular, n = 29; articular, n = 26; left side: muscular, n = 27; articular, n = 36. Exact permutation chi-square test: right: $\chi^2(4) = 21.7$, $p < 0.0001$, and Cramér's V = 0.63; left: $\chi^2(4) = 18.7$, $p < 0.001$, and V = 0.54

TMJ, temporomandibular joint; CBCT, cone-beam computed tomography

Surface electromyography

sEMG was recorded on all 118 sides with a positive test, of which 56 were muscular and 62 articular (both sides pooled). At rest, amplitudes were low and almost identical in the two groups (Table *4*). Differences emerged in maximum intercuspation. Temporalis amplitude was higher on muscular sides ($t(116) = 2.20$, $p = 0.030$, and $d = 0.41$), and masseter amplitude was higher on articular sides, although not significantly ($t(116) = -1.61$, $p = 0.109$, and $d = -0.30$). The masseter on articular sides also showed higher rise values ($t(116) = -3.44$, $p = 0.001$, and $d = -0.63$) and a higher firing rate in MI ($t(116) = -3.59$, $p < 0.001$, and $d = -0.66$).

Parameter	Muscle	Muscular (n = 56)	Articular (n = 62)	t (df = 116)	p	Cohen's d
Amplitude at rest (μV)	Masseter	8.6 ± 0.7	8.6 ± 1.0	0.00	>0.999	0.00
	Temporalis	10.7 ± 0.6	10.3 ± 1.1	0.31	0.757	0.06
Amplitude in MI (μV)	Masseter	143.0 ± 13.8	169.7 ± 9.6	-1.61	0.109	-0.30
	Temporalis	198.0 ± 11.5	161.2 ± 12.0	2.20	0.030	0.41
Rise at rest	Masseter	207.4 ± 43.3	181.6 ± 34.9	0.47	0.641	0.09
	Temporalis	167.6 ± 43.9	229.3 ± 48.7	-0.93	0.352	-0.17
Rise in MI	Masseter	706.0 ± 44.7	878.6 ± 25.3	-3.44	0.001	-0.63
	Temporalis	801.6 ± 38.4	850.5 ± 38.9	-0.89	0.374	-0.16
Firing rate at rest (Hz)	Masseter	20.1 ± 1.5	18.1 ± 1.9	0.81	0.417	0.15
	Temporalis	23.4 ± 1.1	24.1 ± 1.2	-0.43	0.670	-0.08
Firing rate in MI (Hz)	Masseter	21.1 ± 1.7	28.7 ± 1.3	-3.59	<0.001	-0.66
	Temporalis	26.1 ± 1.2	28.0 ± 1.5	-0.98	0.331	-0.18

TABLE 4: sEMG parameters by Krogh-Poulsen group, mean ± SE

The muscular group comprised 56 sides (29 right and 27 left) and the articular group 62 sides (26 right and 36 left). Groups were compared with Student's t-test for independent samples; t and Cohen's d are calculated as muscular minus articular, so negative values indicate higher values on articular sides. Rise is the rise parameter of the motor unit potentials, given in the units returned by the EMG2 software

MI, maximum intercuspation; SE, standard error; df, degrees of freedom; sEMG, surface electromyography

sEMG and condylar morphology

At rest, amplitudes did not vary with condylar type on either side, and in MI, the right side showed no difference either (Table *5*). On the left side, however, masseter amplitude in MI rose from 139.8 ± 11.9 μV on normal condyles (n = 26) to 219.8 ± 15.0 μV on deformed ones (n = 10) ($F(4, 58) = 3.53$, $p = 0.012$, and $\eta^2 = 0.20$), and the difference between types N and D remained significant after Bonferroni correction (mean difference: 80.0 μV; $t(58) = 3.26$ and corrected $p = 0.019$). Left temporalis amplitude in MI showed a trend in the same analysis that did not reach significance ($F(4, 58) = 2.47$, $p = 0.055$, and $\eta^2 = 0.15$) (Figure *2*).

Side	Muscle	Condition	Condyles, n	F	df1	df2	p	η²
Right	Masseter	Rest	55	0.77	4	50	0.550	0.06
	Temporalis	Rest	55	1.37	4	50	0.259	0.10
	Masseter	MI	55	0.43	4	50	0.784	0.03
	Temporalis	MI	55	1.23	4	50	0.309	0.09
Left	Masseter	Rest	63	1.25	4	58	0.299	0.08
	Temporalis	Rest	63	1.89	4	58	0.124	0.12
	Masseter	MI	63	3.53	4	58	0.012	0.20
	Temporalis	MI	63	2.47	4	58	0.055	0.15

TABLE 5: sEMG amplitude according to condylar type (one-way ANOVA)

Root mean square amplitudes were compared across the five condylar types (N, F, E, D, and S) with one-way analysis of variance (ANOVA). Sample size of each subgroup: right side (55 condyles): type N, 25; type F, 16; type E, five; type D, four; and type S, five condyles; left side (63 condyles): type N, 26; type F, 13; type E, nine; type D, 10; and type S, five condyles (see also Table 2)

df1 and df2, degrees of freedom between and within groups; η², eta squared; MI, maximum intercuspation

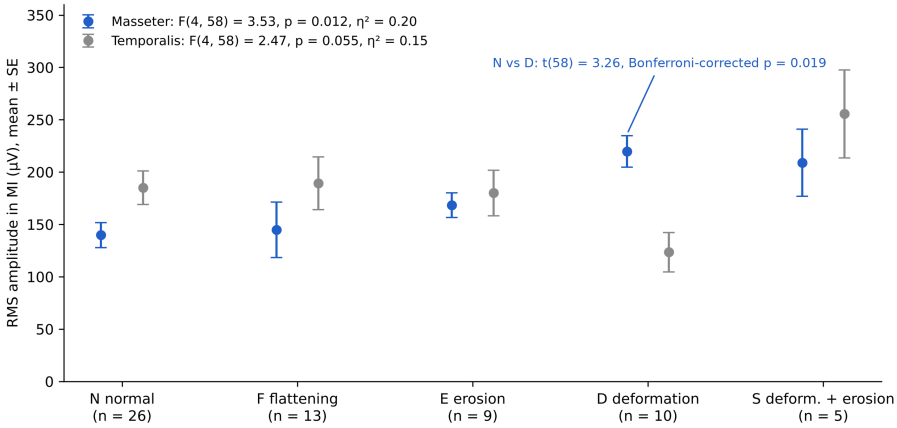


FIGURE 2: Left-side sEMG amplitude in maximum intercuspation according to condylar type

Points are means, and whiskers are standard errors; the number of condyles of each type is given under the axis. One-way ANOVA: masseter: F(4, 58) = 3.53, p = 0.012, and η² = 0.20; temporalis: F(4, 58) = 2.47, p = 0.055, and η² = 0.15. Post hoc comparison of types N and D for the masseter (t-test using the ANOVA error term, with Bonferroni correction): t(58) = 3.26 and Bonferroni-corrected p = 0.019

RMS, root mean square; MI, maximum intercuspation; SE, standard error; sEMG, surface electromyography; ANOVA, analysis of variance

Discussion

In this series, a bite test lasting less than a minute divided patients into two groups that differed clearly on CBCT and, to a lesser extent, on sEMG. Sides classified as muscular rarely showed condylar erosion or deformation (three of 56, 5.4%), whereas more than half of the articular sides did (35 of 62, 56.5%).

Krogh-Poulsen test and CBCT

Although the Krogh-Poulsen test has been taught for decades, objective evidence supporting it remains limited [6,7]. In our patients, an articular response was associated with bony changes on CBCT in more than half of the sides, while a muscular response was associated with a normal or merely flattened condyle in nearly all of them. The size of the association was large on both sides (Cramér's V = 0.63 and 0.54).

Flattening should be interpreted with caution. It was present in both groups, and the RDC/TMD image analysis criteria regard flattening alone as indeterminate, since it may reflect remodelling rather than disease [10]. When flattening is set aside, the contrast becomes sharper still: no erosion or deformation was seen on the right muscular sides, against 14 of 26 articular ones.

This has a practical implication for radiation protection. CBCT delivers a much lower dose than medical CT, but each examination must still be justified [8,31]. Our results suggest that a muscular response to the bite test predicts a normal or near-normal scan in most patients. In that situation, imaging is unlikely to change management, and the as low as reasonably achievable (ALARA) principle argues against it. Conversely, an articular response carries a high probability of bony changes and makes a request for CBCT easier to justify. These implications should nevertheless be interpreted cautiously. Because CBCT and sEMG were performed only on sides with a positive bite test, the findings of negative sides are unknown, and the sensitivity, specificity, and predictive values of the test could not be estimated. Studies in which all sides are examined against an appropriate diagnostic reference standard, such as the full DC/TMD protocol, are required before the bite test can be recommended as a first-line triage tool in routine clinical practice.

Contribution of sEMG

Resting sEMG did not discriminate between the groups. Amplitudes at rest were low and similar, in line with reports that resting activity varies widely between individuals and separates TMD subtypes poorly [13,15]. Recordings during clenching were more informative, although the effects were of small to moderate size (|d| between 0.41 and 0.66). The higher temporalis amplitude on muscular sides is consistent with the altered recruitment of painful muscles, with the anterior temporalis taking a larger share of the load [14]. On articular sides, the masseter showed a higher firing rate and higher rise values during clenching. One interpretation is that the masseter works harder to stabilize a painful or altered joint, although our design does not allow this to be confirmed.

The association between left masseter activity and condylar morphology, with the highest amplitudes over deformed condyles, points in the same direction and may represent the muscular counterpart of joint disease. It should nevertheless be interpreted cautiously. The effect was observed only on the left side, where articular cases were more frequent, the corresponding temporalis analysis did not reach significance, and some subgroups were small. Confirmation in a larger sample is needed before any clinical use.

Strengths and limitations

The main strength of this study is that the three tools were applied to the same patients, with a single CBCT unit, a single sEMG system, and the same examiners throughout, which limits technical variability between measurements. Recruitment was prospective and consecutive, which reduces selection bias, and every comparison is reported with its test statistic, degrees of freedom, and effect size so that the strength of each association can be judged independently of its p value.

Several limitations should be acknowledged. There was no healthy control group, so reference values for sEMG could not be established. The bite test was not compared with the full DC/TMD protocol, and the clinician who performed it also read the scans with the radiologist, which may have introduced bias. CBCT and sEMG were performed only on sides with a positive bite test, so negative sides could not be compared. The sex distribution reflects a military hospital population and limits generalization. The side-based analysis treats the two joints of each patient as independent observations, which they are not, and the pooled sEMG comparisons may therefore slightly overstate statistical significance. Biting force during the test was not measured, and the inter-examiner reliability of the test was not assessed. Finally, the test statistics were recalculated from summary data, and some condylar subgroups were small, although the exact tests used for the condylar comparisons are not biased by small cell counts.

Conclusions

In this group of 88 adults, the Krogh-Poulsen test distinguished muscular from articular TMD in a way that CBCT confirmed on both sides. sEMG recorded during clenching added functional information, with greater temporalis activity on muscular sides and greater masseter activity on articular sides. These findings suggest that the bite test may help to orient the indication for CBCT and the use of sEMG after the history and palpation. However, because CBCT and sEMG were performed only on sides with a positive test, this approach cannot yet be recommended for routine clinical practice. Further studies, including a control group, the examination of all sides, and the full DC/TMD protocol as the reference standard, are needed to establish the sensitivity and specificity of the bite test.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. The Scientific Council of the Faculty of Medicine of the University of Algiers 1, Algiers, Algeria, issued approval 25. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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