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Clinical, radiographic, and electromyographic study of patients with internal derangement of the temporomandibular joint

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Fifteen patients with internal derangement of the temporomandibular joint (TMJ) were examined clinically, radiographically, and electromyographically. Electromyographic recordings were also obtained from 11 subjects without signs or symptoms associated with their TMJs or masticatory musculature. All the patients with internal derangement demonstrated interferences on the ipsilateral side. This was interpreted as the result of disc displacement producing a reduced joint space and, consequently, a decreased vertical dimension on the symptomatic side. Slow opening and closing mandibular movements without clenching could be performed by healthy persons without noticeable EMG activity in the temporalis and masseter muscles. In association with disc displacement, electromyographic activity of the temporalis and masseter muscles occurred when the condyle slid over the posterior band of the disc and could be interpreted as an arthrokinetic reflex caused by distraction. Continuous muscle activity could be provoked by TMJ disc displacement and ceased when the disc position was normalized on mouth opening, only to occur again every time the disc became displaced on mouth closure. Anterior disc displacement without reduction (closed lock) could cause spastic activity in the temporalis muscle on the affected side. Spastic activity of the masseter and temporalis muscles occurring on the same side as a joint with anterior disc displacement hinders or inhibits the condylar movement necessary to achieve reduction. (Am J Orthod **88:** 453-460, 1985.)

Key words: Temporomandibular joint, internal derangement, radiography, EMG, arthrokinetic reflex

Disc displacement of the temporomandibular joint (TMJ) has been considered a fundamental pathophysiologic abnormality of the joint.[1-4]

Anterior disc displacement can be subdivided into:

1. Displacement with reduction—Repositioning of the disc to a normal disc-condyle relationship during opening mandibular movements
2. Displacement without reduction—No repositioning of the disc to a normal disc-condyle relationship during mandibular movements with the disc remaining displaced. The disc thereby obstructs normal condylar translation, which results in decreased mandibular movements.

A clinical sign of anterior disc displacement with

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reduction is reciprocal clicking—clicking that occurs at an early, intermediate, or late phase during opening and preceded by a click during the final stage of closure.[5-7] Disc displacement without reduction is clinically characterized by a history of clicking followed by a limitation of opening ability without clicking.[1-4,8]

It has been clinically observed that patients with disc displacements demonstrate various symptoms from the TMJ and masticatory muscles.[4] Nanthaviroj and associates[9] performed an electromyographic (EMG) study on patients with TMJ clicking and suggested that clicking/locking may cause an incoordination of the EMG pattern of the masticatory muscles. Widmalm and Hedegård[10,11] studied the jaw jerk stretch reflex and found that a reflex response, similar to the monosynaptic compound action potential evoked by a chin tap, sometimes occurred in jaw elevator muscles during TMJ clicking. This reflex response was designated *t*emporomandibular *m*ono*s*ynaptic compound action *p*otential (TMSP).[12]

The aim of this study was to provide more information about the relationship between mandibular and disc movements and activity in the masseter and temporalis muscles in patients with TMJ disc displacements (also known as internal derangements).

MATERIAL

A consecutive sample comprised fifteen patients (seven males and eight females) with diagnoses of anterior disc displacement with reduction (clicking). The age range was 23 to 57 years with a mean of 34 years.

A control group consisting of eleven persons, five males and six females with an age range of 17 to 57 years and a mean age of 33 years, was chosen. These persons demonstrated no signs or symptoms from their TMJs or masticatory muscles.

METHODS

Clinical history and examination

A clinical history was obtained that included duration of clicking symptoms, trauma to the mandible associated with the onset of clicking, pain during mandibular movement, hesitation/transient locking during opening and/or closing, bruxism, frequency and severity of headaches, previous orthodontic treatment, and symptoms in other joints.

A clinical examination was performed by two of the authors (A.I. and R.I.) that documented early, intermediate, or late reciprocal clicking, range of jaw movements, TMJ and muscle tenderness, type of occlusion, and occlusal interferences. Eleven of the patients were reexamined after 10 months; of these, eight were examined again 5 years later.

Radiography

The patients were radiographically examined to document hard-tissue changes within their TMJs. The examination included submento-vertical (axial) projection, transcranial projection at closed mouth position and maximal opening, serial lateral tomography at closed mouth position, and frontal projection. In one subject double-contrast arthrography according to Westesson[13] was performed after the second examination to obtain information about disc configuration and soft-tissue changes within the joint.

Simultaneous registration of mandibular movements and clicking

The condylar path, movement of the mandibular midline, and clicking were simultaneously registered according to Isberg-Holm and Ivarsson[14] and Isberg-Holm.[15] The patient was placed in a cephalostat; condylar movements were registered cineradiographically in a lateral transcranial projection with an inclination of the x-ray beam of 20° to the horizontal plane. The cineradiographic registration was stored on videotape. The most superior point of the condylar outline, identified with the condyle in the fossa, was marked on the cineframe tracings. The condylar paths were obtained by connecting these markings.

Movement of the mandibular midline was simultaneously registered by two TV cameras that depicted an indicator fixed between the lower incisors and traced its movement relative to a vertical reference line in frontal and lateral views. The signals from the two TV cameras were recorded on videotape. Clicking was simultaneously recorded by a contact microphone.* This signal was graphically displayed on an oscilloscope† that was filmed by a TV camera and stored on videotape. By displaying the videotape recordings on split-viewing screens, simultaneous documentation of condylar movement, clicking, and mandibular movements could be obtained.

Simultaneous registration of electrical muscle activity and clicking

Bipolar silver disc-electrodes were used for bilateral recordings of electrical activity in the anterior temporalis and masseter areas. Most of the recorded activity can be presumed to originate from the temporalis and

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†Medelec Ltd., London.

masseter muscles and will be referred to as such, even if the possibility that some of the observed activity was coming from the superficial subcutaneous muscles (for example, epicranieus) and/or deeper muscles (such as pterygoids) can not be excluded. The signals were conventionally amplified* by means of a lower frequency cutoff (LF) at 16 Hz and a higher frequency cutoff (HF) at 3200 Hz. Clicking was detected by a piezo-electric microphone attached to the patient's forehead (LF 16 Hz, HF 800 Hz).

Recordings of joint sounds and muscle activity were made during a minimum of 10 consecutive slow opening and closing movements. The opening and closing phases were separated in the recordings by an artifact signal superimposed on the microphone channel at maximum jaw opening.

After the initial registration, all interferences in the intercuspal and retruded positions were removed. The patients were then given a thin, equilibrated acrylic splint to use at night. After delivery the splint was regularly checked and adjusted. Mandibular movement, clicking, and EMG registrations were repeated after 10 months in 11 of the 15 patients. (Four patients were unavailable for various reasons.)

EMG and sound recordings were also performed on the subjects in the control group.

RESULTS

Clinical history

The duration of clicking ranged between ½ and 29 years with a median and mean of 4 years. Clicking appeared immediately after severe trauma to the mandible in one third of the subjects (car accident—1, boxing knockout—1, fall on the cheek—1, blow to the mandible—2). In two of these patients, this resulted in opening locking (condylar dislocation). The luxated condyles had been repositioned into the fossae during general anesthesia. Four patients experienced transient locking during opening. One of them suffered from anterior disc displacement without reduction involving the contralateral TMJ. One patient with reciprocal clicking developed anterior disc displacement without reduction during the investigation period. Clicking disappeared and mouth opening became limited. The condition was remedied after 2 weeks by manipulation of the disc into a correct position, momentarily normalizing the range of opening ability and lateral mandibular movements. Disc displacement with reduction occurred again.

Pain during mandibular movement was present in 10 patients. Frequent headaches (daily or at least once a week) were reported in five patients, all showing late clicking. Four of these experienced additional hesitation/locking during opening.

Three patients had previously received orthodontic treatment. Two thirds (10) of the patients bruxed. One patient suffered from pain of nondiagnosed character involving other joints.

Clinical examination

Clicking occurred early during the opening phase in two patients, was intermediate in one patient, and late in twelve patients. Maximum opening was within normal limits in all cases except in those patients with anterior disc displacement without reduction or during occasional transient locking.

Muscle tenderness was registered at palpation in the masseter in six patients, the temporalis muscle in three patients, and the lateral pterygoid in one patient. Lateral and/or posterior tenderness of the TMJ was present in five patients including the patient with unilateral anterior disc displacement without reduction.

Two patients demonstrated a large, vertical overbite (>4 mm). One patient had a postnormal bite.

Interferences in retruded contact position were present in all patients and occurred consistently on the same side as the disc displacement. Interferences in the intercuspal position were found in 12 patients, usually on the side with anterior disc displacement.

Eleven patients were examined again after 10 months. In eight patients, the signs and symptoms from their TMJs remained the same. Of the others, one patient was symptom-free, one with early clicking demonstrated late clicking, and one developed anterior disc displacement without reduction.

At the 5-year examination, the eight patients examined showed symptoms that had varied over the years, but had on the whole persisted.

Radiology

None of the patients demonstrated any radiographic signs of hard-tissue changes within their TMJs. Double-contrast arthrography in one patient confirmed the diagnosis of anterior disc displacement and showed that the disc was still biconcave although thickened and without perforation (Fig. 1).

Simultaneous registration of mandibular movements and clicking

Graphs representing mandibular midline movements in patients with unilateral clicking showed a deviation toward the affected side in association with the

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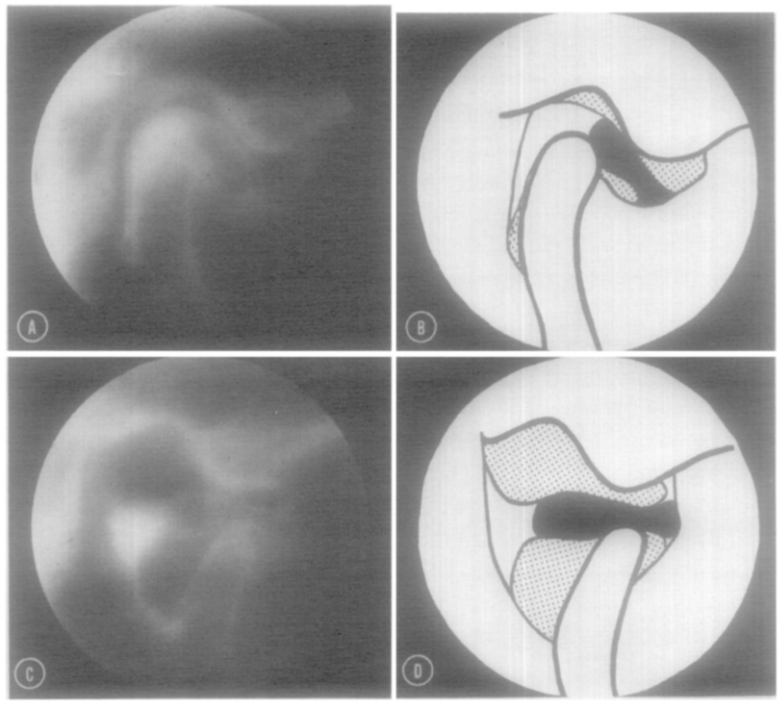

Fig. 1. Double-contrast arthrograms of a patient with anterior-disc displacement with reduction. **A,** The disc becomes anteriorly displaced during mouth closure. **B,** Schematic drawing. The disc is marked in black. **C,** The disc position is normalized on opening. **D,** Schematic drawing. The disc is marked in black.

clicking. After the click, the midline returned to a centered position. In patients with bilateral clicking, a deviation took place toward the side where the first click occurred. After the second click had occurred on the opposite side, the mandibular midline moved to a centered position again.

In the one patient with anterior disc displacement without reduction on one side and anterior disc displacement with reduction on the other side, a deviation was seen toward the side without reduction and a centered midline position never returned. This same pattern occurred during the second registration of another patient who developed an anterior disc displacement without reduction after the first testing. During the first registration when reduction was still present, the midline moved toward a centered position after clicking, but not when transient locking and anterior disc displacement without reduction occurred.

The patient who was symptom-free at the second recording session showed centered midline mandibular movements.

The simultaneous registration of the condylar path and clicking showed that the condylar paths were similar to those expected when disc displacement with reduction is present and the condyle slides on and off the disc. The difference in the bulge location during opening and closing excluded the possibility of clicking from an uneven articulating surface.

Simultaneous registration of electrical muscle activity and clicking

In 12 patients muscle activity was registered when the condyle was about to slide over the posterior thick part of the disc (clicking) during both opening and closing (Fig. 2).

When transient locking occurred, nonfunctional EMG activity was seen in the ipsilateral temporalis in all cases. Two of these patients with bilateral clicking showed EMG activity in both temporalis muscles. Such activity was not seen when the same joints moved without clicking. In one patient with clicking and transient locking, activity was seen but only during the sequences when the disc was anteriorly displaced (Fig. 3). The activity began when the disc became displaced anterior to the condyle as indicated by a closing click. The activity stopped when normal disc position was restored (opening clicking). This EMG pattern was consistent during consecutive registrations.

One patient was first tested when alternating between clicking and transient locking, and tested again 10 months later in a closed-lock condition (Fig. 4, *A-C*). During clicking (Fig. 4, *A*), a stretch reflex re-

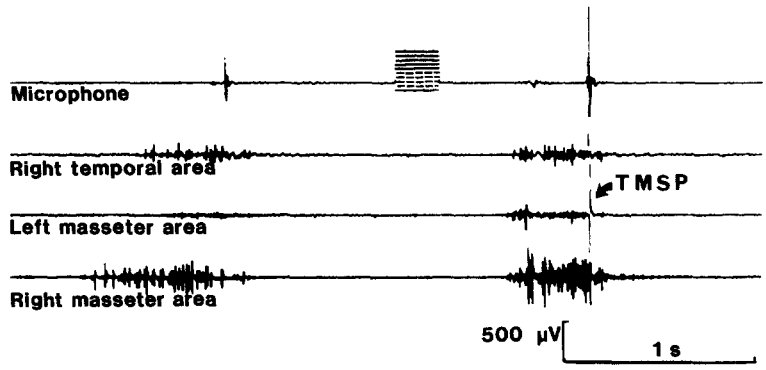

Fig. 2. Clicking from the right TMJ is registered by means of a microphone and visualized as a deflection on a paper graph. An artefact signal marks maximum opening. Before the opening click (that is, immediately before the condyle passes the posterior ridge of the disc to achieve a normal relationship), activity is registered in the temporalis and masseter muscles of the ipsilateral side. Activity is registered again before the closing click (that is, immediately before the condyle slides off and behind the disc). A TMSP is seen in association with clicking.

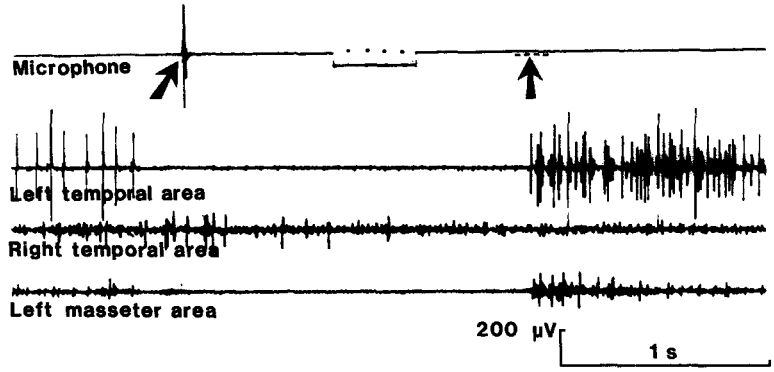

Fig. 3. Clicking from the left TMJ is registered by means of a microphone and visualized on a paper graph. An artefact signal separates opening and closing movements. The *left arrow* indicates clicking that arises in association with restoration of the condyle and disc relationship. The *dotted line* indicates when the condyle slides off the disc again (documented cineradiographically). During the sequence when the disc/condyle relationship is normal (between arrows), no activity is observed on the affected side during opening or closing mandibular movements. However, in the temporal area of the ipsilateral side, activity is registered during periods when the disc is displaced. No such activity could be seen in the control subjects during corresponding mandibular movements.

sponse was seen in the contralateral temporalis muscle in association with an opening click. EMG activity was also noted in association with a closing click. During periods of transient locking (Fig. 4, *B*), no clicking was registered as the disc stayed anterior to the condyle during the entire opening and closing cycle. The ipsilateral temporalis muscle then demonstrated activity. When the patient's condition had progressed to a closed lock with the disc permanently displaced anterior to the condyle (Fig. 4, *C*), the temporalis muscle of the affected right side demonstrated continuous activity. The contralateral temporalis muscle also showed continuous activity.

Continuous activity at rest was observed in the temporalis muscles in eight of fifteen patients. The activity had the character of repeatedly firing single motor units. No differences in contraction or resting activity were observed between the first and second sessions in the 10 patients with unchanged symptoms. In the patient who was symptom-free at the second registration, activity present at the first session was absent at the second registration.

TMSPs were observed in association with clicking in nine of fifteen patients. In six patients unilateral clicking was associated with TMSPs in their contralateral temporalis and/or masseter muscles. Two patients demonstrated bilateral clicking and bilateral TMSPs; in one patient TMSPs always occurred on the same side

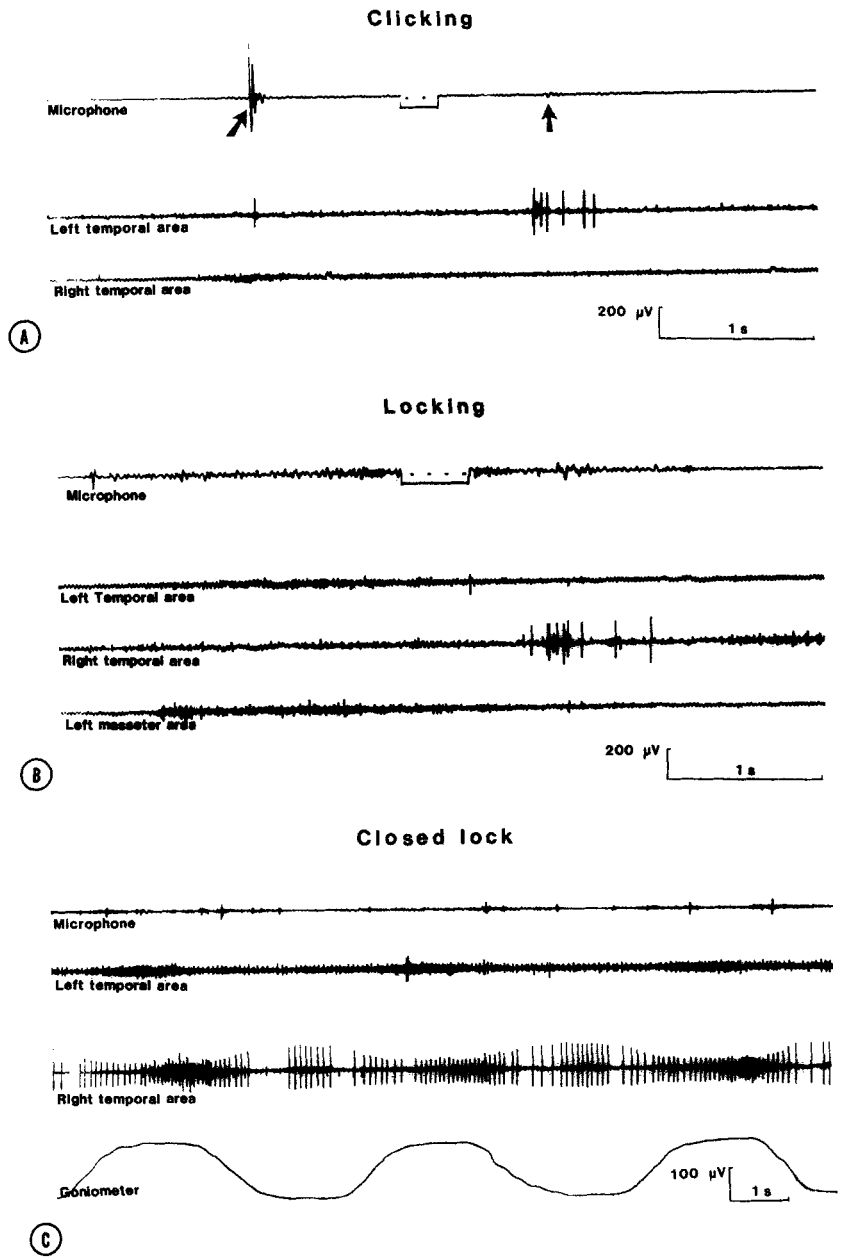

Fig. 4. A patient is registered during a period of alternate clicking **(A)**, transient locking **(B)**, and, on a later occasion, at an aggravated stage of closed lock **(C)**. The patient performs slow opening and closing mandibular movements that could be performed by the control subjects without observable EMG activity. **A,** The microphone registrations of clicking are marked with *arrows*. An artefact signal separates opening and closing movements. The left temporal area on the nonclicking side demonstrates a stretch reflex in association with opening clicking and a short period of activity in association with closing clicking (that is, when the condyle slides off the disc). **B,** When periods of transient locking occur, no clicking is registered as the disc stays displaced anterior to the condyle during the entire opening and closing movement. A period of EMG activity is seen in the temporal area on the affected side. **C,** On a later occasion when the patient has developed a condition of anterior-disc displacement without reduction (closed lock), the temporal area of the affected side demonstrates continuous activity. A goniometer indicates opening and closing—the top of the curve represents opening and the bottom indicates closure.

as the clicking. TMSPs occurred during opening clicking in six patients and during closing in three. TMSPs were observed in only two of the eleven patients at the second examination.

All subjects in the control group could perform slow opening-closing movements without observable activity in the temporalis or masseter muscles except when tooth contact occurred. No activity was seen when the mandible was at rest.

DISCUSSION

Vitti and Basmajian[16] showed that slow opening and closing movements could be performed without any notable muscle activity in the temporalis muscles. Our results from healthy subjects agreed with their findings and showed the same results for the masseter muscle.

Masticatory muscle activity can be provoked by TMJ disc displacement according to our study. This activity ceased when the disc position was normalized on mouth opening, only to occur again each time the disc became displaced on mouth closure. When a disc has become anteriorly displaced, a prerequisite for normalization is that the condyle can move downward and forward, passing over the posterior thick part of the disc. Muscle activity in the elevator muscles opposes the downward movement of the condyle pulling against the tubercle. During opening the anteriorly displaced disc thus acts as a wedge rendering correction of disc position more difficult. In joints with reducing disc displacement, it is likely that nonfunctional muscle activity of the masseter and temporal muscles during opening aggravates the development of a closed-lock condition because such activity may prevent the condyle from passing over the posterior band of the disc to restore normal disc/condyle relationships.

When the condyle passes the posterior band of the disc (clicking), the bony joint components are distracted. Muscle activity in association with this condylar movement is likely to be caused by an arthrokinetic reflex similar to the protective response seen in other joints.[17]

TMSPs were observed in 40% of the patients and arose when the condyle slid over the posterior thick part of the disc causing an opening click. The irregular mandibular movement, seen as a bulge in the condylar path and a deviation in mandibular midline movement, indicated that the muscles in the masseter and temporal areas were stretched on the contralateral side when the disc became displaced or reduced. The fast upward movement of the condyle in association with clicking[7,14] is related to a simultaneous downward movement of the contralateral condyle. This downward movement may be too small to be detected in graphic recordings of the condylar path, but sufficient enough to elicit a stretch reflex response.[18] The stretch reflex functions in the neuromuscular system to control muscle length and hence joint position.[19]

The absence of TMSPs during clicking, however, does not necessarily indicate the absence of stretching. It is known that a firm chin tap fails to evoke a stretch reflex in some persons.[22] Sensitivity for the stretch reflex is increased, however, in tensed muscles.[20] An overall reduction in the tonus of the jaw muscles might therefore explain the decrease of TMSPs observed during the second session.

When the disc is anteriorly displaced during mouth opening, it prevents the ipsilateral condyle from moving freely while the contralateral condyle continues its translation. The mandibular midline thus deviates toward the ipsilateral side. Clicking that occurs during opening is a sign that the condyle has passed over the posterior thick part of the disc into a normal position underneath the disc.[7] The disc is then no longer an obstacle for condylar movement and the mandibular midline returns to a centered midline position again. The movement pattern of the mandibular midline recorded in this study agreed with the results of Isberg-Holm.[15]

When the disc becomes anteriorly displaced, the joint space often narrows, particularly postero-superiorly.[4,6] Consequently, the mandible is pushed backward-upward and occlusal interferences are likely to occur, particularly on the ipsilateral side. This explains why all patients in this study demonstrated interferences in the retruded position on the side where the disc was displaced. Twelve patients demonstrated additional interferences in the intercuspal position. Occlusal interferences that occur as a result of disc displacement should therefore not be removed until the disc position has been normalized.

Removal of interferences and the use of a thin equilibration splint was fully successful in eliminating symptoms in only one of the patients reexamined after 10 months. After a further 5 years, eight reexamined patients still suffered from disc displacement. The reason so many reexamined patients (ten out of eleven and eight out of eight) still had symptoms is in part because most patients demonstrated late opening clicking. This indicates a more pronounced degree of damage to the posterior disc attachment.[2,21] The prognosis of treatment in these cases is probably guarded. Splint design was not deliberately intended to keep the disc in a reduced position, but only to help stabilize the occlusion. Consequently, most patients still demonstrated clicking when using the splint.

It may be concluded that in cases where muscle activity is triggered by a faulty disc position, as long as the disc is not prevented from being displaced, symptoms are likely to persist in spite of the removal of occlusal interferences and the use of a splint.

CONCLUSIONS

1. Slow opening and closing mandibular movements without clenching can be performed by healthy persons without any noticeable EMG activity in the temporalis and masseter muscles.

2. EMG activity of the temporalis and masseter muscles occurring when the condyle slides over the posterior band of the disc can be interpreted as an arthrokinetic reflex caused by distraction.

3. Continuous muscle activity can be provoked by TMJ disc displacement and ceases when the disc position is normalized on mouth opening, only to occur again each time the disc becomes displaced on mouth closure.

4. Anterior disc displacement without reduction (closed lock) may cause spastic activity in the temporalis muscle on the affected side.

5. Spastic activity of the masseter and temporalis muscles, occurring on the same side as a joint with anterior disc displacement, hinders or inhibits the condylar movement necessary to achieve reduction.

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REFERENCES

1. Wilkes CH: Arthrography of the temporomandibular joint in patients with the TMJ pain-dysfunction syndrome. Minn Med **61:** 645-652, 1978.
2. Wilkes CH: Structural and functional alterations of the temporomandibular joint. Northwest Dent **57:** 287-294, 1978.
3. Katzberg RW, Dolwick MF, Helms CA, Hopens T, Bales DI, Coggs GC: Arthrotomography of the temporomandibular joint. AJR **134:** 995-1003, 1980.
4. Eriksson L, Westesson P-L: Clinical and radiological study of patients with anterior disc displacement of the temporomandibular joint. Swed Dent J **7:** 55-65, 1983.
5. Ireland VE: The problem of "the clicking jaw." Proc R Soc Med **44:** 363-372, 1951.
6. Farrar WB: Characteristics of the condylar path in internal derangement of the TMJ. J Prosthet Dent **39:** 319-323, 1978.
7. Isberg-Holm A, Westesson P-L: Movement of disc and condyle in temporomandibular joints with and without clicking. A high-speed cinematographic and dissection study on autopsy specimens. Acta Odontol Scand **40:** 167-169, 1982.
8. Dolwick MF, Katzberg RW, Helms CA, Bales DJ: Arthrotomographic evaluation of the temporomandibular joint. J Oral Surg **37:** 793-799, 1979.
9. Nanthaviroj S, Omnell K-Å, Randow K, Öberg T: Clicking and temporary "locking" in the temporomandibular joint. A clinical, radiographical and electromyographical study. Dentomaxillofac Radiol **5:** 33-38, 1976.
10. Widmalm S-E, Hedegård B: Reflex activity in the masseter muscle of young individuals. I. J Oral Rehabil **3:** 41-55, 1976.
11. Widmalm S-E, Hedegård B: Reflex activity in the masseter muscle of young individuals. II. J Oral Rehabil **3:** 167-180, 1976.
12. Widmalm S-E: Reflex activity of the masseter muscle in man. An EMG study. Acta Odontol Scand **34**(Suppl): 72, 1976.
13. Westesson P-L: Double-contrast arthrotomography of the temporomandibular joint. Introduction of an arthrographic technique for visualization of the disk and articular surfaces. J Oral Maxillofac Surg **41:** 163-168, 1983.
14. Isberg-Holm A, Ivarsson R: The movement pattern of the mandibular condyles in individuals with and without clicking. A clinical and cineradiographic study. Dentomaxillofac Radiol **9:** 59-69, 1980.
15. Isberg-Holm A: Simultaneous registration of mandibular movements and sound in patients with temporomandibular joint clicking. Dentomaxillofac Radiol **11:** 69-75, 1982.
16. Vitti M, Basmajian JV: Integrated actions of masticatory muscles: Simultaneous EMG from eight intramuscular electrodes. Anat Rec **187:** 173-189, 1977.
17. Wyke B: The neurology of joints: A review of general principles. Clin Rheum Dis **7:** 223-239, 1981.
18. Matthews PBC: Mammalian muscle receptors and their central actions. London, 1972, Arnold, E. & Co., Ltd.
19. Houk J, Henneman E: Feedback control of muscle. *In* Mountcastle VB (editor): Medical physiology, ed 13, vol 1. St. Louis, 1974, The C. V. Mosby Company, pp 608-616.
20. Lance JW, McLeod JG: A physiological approach to clinical neurology, ed. 3. London, 1981, Butterworth and Co.
21. Farrar WB, McCarthy WL Jr: Inferior joint space arthrography and characteristics of condylar paths in internal derangement. J Prosthet Dent **41:** 548-555, 1979.
22. Widmalm S-E, Gill H, Widmalm SE, Ericsson SG: Standard values of the amplitude of jaw jerk action potential and differences due to age, sex and L-dopa treatment. J Dent Res **58:** 1337-1340, 1979.

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