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# NEED OF FUNCTIONAL ANALYSIS AND SELECTIVE GRINDING IN ORTHODONTICS
## A CLINICAL AND ELECTROMYOGRAPHIC STUDY

*by*

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## INTRODUCTION

The purpose of the present work is to assess the incidence of cuspal interferences (see below) in children before and after orthodontic treatment. Further it was attempted to evaluate the need and indication of occlusal adjustment by grinding[1]) after the completion of orthodontic treatment.

### *Cuspal interferences*

By cuspal interferences is meant tooth contacts forcing the mandible to deviate from a physiologic movement pattern. Cuspal interferences may occur in connection with habitual closure and terminal hinge closure as well as during gliding movements (articulation).

In most normal, natural dentitions contact in the terminal hinge position occurs on two or more retrusion facets. Full intercuspation then causes the mandible to slide about 1 mm forward

[1]) Occlusal adjustment by grinding: Grinding of the occlusal areas in order to eliminate cuspal interference by distributing the stresses and applying them axially to the teeth (*Posselt* 1962).

to the intercuspal position[1]). This condition is considered by some authors to be normal (*Beyron* 1954, 1962; *Posselt* 1952, 1956, 1962). If the slide, however, has a direction not only anteriorly but also laterally from the retruded contact position to the intercuspal position, then an interference is present. This condition often results in joint and muscle strain. With regard to gliding movements (articulation) interferences on the non-working (balancing) side is considered to be the most severe (*Ramfjord* 1961 a, 1961 b).

Cuspal interferences and other occlusal disharmonies[2]) may cause functional disturbances of the masticatory system (*Berlin et al.* 1956, *Beyron* 1954, *Hankey* 1956, *Jarabak* 1957, *Perry* 1957, *Posselt* 1958 b, 1959, 1961, *Ramfjord* 1961 a, 1961 b, *Shore* 1959, and *Thielemann* 1956). It has been demonstrated through experiments that when the mandible is shifted horizontally away from its natural relationship to the maxilla as determined by joints and muscles ("centric"), then muscular reactions with or without pain rapidly occur (*Ahlgren* 1960, *Brill et al.* 1962, *Moyers* 1956 a). The changes in the periodontium and alveolar bone should be seen as slow and long term developments, evoked by muscular hypofunction or hyperfunction.

In general, it is not likely that a cuspal interference will be eliminated through attrition or through a change in tooth position, as interferences are usually avoided by neuromuscular reflexes aiming to protect periodontal membranes and temporomandibular joints from undue loads (*Grewcock & Ballard* 1954, *Lewinsky & Stewart* 1936, *Moyers* 1956 a, 1956 b, *Ness* 1954, *Pfaffman* 1939, and *Thilander* 1961).

### *Morphologic versus functional malocclusion*

Most classifications of malocclusion are based on morphologic rather than on functional criteria, and thus give no information

[1]) Intercuspal position: The intermaxillary relationship when intercuspation has occurred upon closure. This is usually the most cranial position of the mandible in which the cusps and sulci of the mandibular and maxillary teeth mesh tightly (*Posselt* 1962).

[2]) Occlusal disharmony: An occlusal form and/or intermaxillary relationship out of harmony with the individual pattern of movement. Cuspal interferences and other occlusal disharmonies may lead to functional disturbances of the masticatory system (*Posselt* 1962).

regarding the functional status of the dentition. It is very likely that malocclusions in general have a disturbing influence upon the functions of the stomatognathic system. However, the interconnection between malocclusion in a morphological sense and occlusal disharmony (functional malocclusion) is practically unknown. Classical works by *Angle* 1907, *Simon* 1925, and others stress morphological rather than functional aspects of malocclusion. *Simon* was aware of the problems of function but his concern was limited to philosophical considerations without practical application. *Andresen-Häupl* 1942 discussed the concept of function extensively but mostly in relation to their treatment system, "functional jaw orthopedics".

Later *Thompson* and others introduced a more functional approach to the study of malocclusion of the teeth (*Grewcock & Ballard* 1954, *Moyers* 1956 a, 1958, *Perry* 1957, *Thompson & Craddock* 1949, *Thompson* 1954, 1956). However, it is still not known, whether or not occlusal disharmony influences the development of the growing dentition. *Moyers* (1956 a, 1956 b) and *Perry* (1960) have stated that cuspal interferences should be diagnosed and corrected as early as possible in order to avoid an ensuing morphologic deviation. *Seipel* 1948 has shown that if a temporary functional deviation is persisting during a certain length of time bone adaptation and trajectorial readjustment will follow.

*Functional analysis (occlusal analysis)*[1] *and occlusal adjustment*

Occlusal disharmonies and their possible connections with functional disturbances and disorders can be demonstrated only by a functional examination of the masticatory system, bearing in mind the gradual development and indirect, accumulative effect of occlusal disharmonies. What at first glance may seem a relatively harmless condition may through gradual secondary changes lead to dysfunctions and deterioration of the dentition.

Some authors have pointed out the risk of introducing cuspal interferences due to previously made orthodontic treatment as well as the importance of adjusting the occlusion by grinding after orthodontic treatment. By selective grinding it should be

[1]) Occlusal analysis: The examination of the occlusion and articulation of the teeth and evaluation of functional disturbances and functional disorders of the masticatory system (*Posselt* 1962).

possible to obtain occlusal harmony both in the centric position and during contact movements. This should also be considered to render better retention and more stability to the dentition (*Coleman* 1948, *Heimlich* 1951, *McCollum* 1943, *Moyers* 1958, *Parfitt* 1960, *Rothner* 1952, *Schuyler* 1954, *Stallard* 1937, *Sved* 1960, *Thompson & Craddock* 1949, *Thompson* 1956).

As *Wylie* (1958) points out it is questionable whether selective grinding to be done in some cases after the completion of orthoment due to the fact that the position of teeth will settle after the orthodontic movement; only "the most obvious sort of equilibration should be done when the bands are removed. When the dentition and tooth position seems stable it might in some cases be wise to grind and in that case the adjustable articulator may be of use".

*Lucia* (1961) who otherwise rejects selective grinding as a permanent method to obtain occlusal harmony, but advocates complete prosthetic reconstruction, does recommend selective grinding to be done in some cases after the completion of orthodontic treatment. The grinding procedure should, however, be made very cautiously and only after exact planning and continuous checking during the treatment.

Generally speaking, occlusal disharmonies being purely functional concepts may be present in any type of malocclusion as well as in morphologically normal dentitions (*Posselt & Nohrström* 1960). Many malocclusions seem to exhibit an adequate function and maintain dental health throughout life. Class II, Div. 2 and "genuine" Class III malocclusions are not considered to undergo any pathologic changes although they exhibit no ideal tooth alinement from a morphologic point of view.

On the other hand, there is evidence that a faulty occlusion may have a detrimental effect on the whole masticatory system and may contribute to an early loss of teeth. But what is the difference then between those malocclusions which maintain dental health and those which undergo some form of disorder or disease? So far it has not been possible to indicate definitely any specific morphological factor which leads to unfavourable occlusal development.

In other words, no investigations have illustrated whether or not occlusal disharmonies are more frequent in cases of malocclusion (morphologic) than in cases of normal occlusion. Perhaps malocclusions are equally or more satisfactory from a functional standpoint than many so-called normal occlusions.

*Statement of the problems*

The following problems should if possible be elucidated or answered:

1) What is the occurrence of cuspal interferences before and after orthodontic treatment?
   a) Distribution of different occlusal disharmonies (cuspal interferences) in 120 untreated patients.
   b) Distribution of different occlusal disharmonies (cuspal interferences) in 23 patients having undergone orthodontic treatment.
2) Is there any interconnection between morphological malocclusion and functional malocclusion (cuspal interference)?
3) Can the electromyographically[1]) recorded muscle pattern be used as a test of the function of the mandible?
4) Does occlusal adjustment by grinding after orthodontic treatment improve the movement pattern of the mandible?

Answers to these questions are essential to orthodontic diagnosis, treatment and prognosis. The present investigation is a beginning of a fairly large investigation illustrating the occurrence of cuspal interferences in orthodontic patients.

## MATERIAL AND METHODS

### Individuals examined

a) *Pre-treatment group*

120 patients were taken from the file of the Orthodontic Department, Folktandvården, County of Stockholm, in order to estimate the incidence of cuspal interferences in a non-treated orthodontic material. No treatment was started prior to the in-

[1]) Hereafter, the adjective electromyographic is abbreviated to emg and the noun electromyograph and electromyogram to EMG.

**Table I**

*General and Orthodontic Data.*

| No. | Name | Sex | Age at the end of treatment (yrs) | Malocclusion (Angle) | Treatment-time (yrs) | Orthodontic appliance[1]) | Cuspal interference[2]) Closing movement[3]) | Cuspal interference[2]) Gliding movement | Electromyogram before occ. adjustment no. | Electromyogram after occ. adjustment no. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B.S. | M | 15 | Class I | 0.2 | — | pos. | neg. | 1 | 1 |
| 2 | B.Å. | M | 15 | Class II, 1 | 7.0 | F, R | pos. | pos. | 1 | 1 |
| 3 | D.S. | F | 18 | Class II | 1.5 | L | pos. | pos. | 1 | 1 |
| 4 | K.C. | M | 12 | Class II | 2.5 | R | pos. | neg. | 1 | 1 |
| 5 | P.A. | M | 11 | Class II, 1 | 2.0 | R | pos. | neg. | 1 | 1 |
| 6 | G.V. | F | 14 | Class II, 1 | 0.5 | — | pos. | neg. | 1 | 1 |
| 7 | G.E. | M | 13 | Class I | 4.5 | F, R, L | pos. | neg. | 1 | — |
| 8 | T.Ö. | M | 12 | Class I | 0.5 | — | neg. | pos. | 1 | — |
| 9 | P.L. | M | 14 | Class II, 1 | 5.0 | F, R | neg. | neg. | 1 | — |
| 10 | K.H. | F | 14 | Class I | 4.0 | F, R, L | neg. | neg. | 1 | — |
| 11 | T.H. | M | 14 | Class II | 2.0 | L | neg. | neg. | 1 | — |
| 12 | W.C. | M | 14 | Class II, 1 | 3.5 | L | pos. | pos. | 2 | — |
| 13 | M.P. | M | 14 | Class II, 1 | 3.0 | L | pos. | pos. | 2 | — |
| 14 | K.D. | M | 13 | Class II, 1 | 4.0 | R, L | pos. | pos. | 1 | — |
| 15 | C.L. | F | 15 | Class II, 1 | 3.0 | L | neg. | neg. | — | — |
| 16 | B.B. | F | 15 | Class II | 5.0 | R, L | neg. | neg. | — | — |
| 17 | T.M. | M | 14 | Class II | 4.0 | F, R | pos. | pos. | — | — |
| 18 | I.V. | M | 14 | Class I | 4.0 | F, R, L | neg. | neg. | — | — |
| 19 | U.L. | M | 15 | Class I | 5.0 | F, L | neg. | neg. | — | — |
| 20 | L.H. | F | 17 | Class II | 4.0 | F, R | neg. | neg. | — | — |
| 21 | A.K. | F | 13 | Class III | 4.0 | R | pos. | neg. | — | — |
| 22 | A.A. | M | 12 | Class II, 1 | 3.5 | L | neg. | pos. | 1 | — |
| 23 | K.W. | F | 15 | Class II, 1 | 3.5 | L | neg. | neg. | 1 | — |
| | | | Mean = 14 | | Mean = 3.3 | | | | | |

[1]) Fixed appliance = F, Removable appliance = R, Loose appliance = L, No appliance = —.

[2]) pos. indicates positive finding, neg. indicates negative finding.

[3]) Interferences in symmetric (approximately terminal hinge) closure are counted only when the antero-posterior difference between the retruded and the intercuspal positions exceeds 1 mm and when a lateral slide between these positions occurs.

vestigation. The age range of this group was from 7 to 15 years with a mean of 11 years. The severity of the malocclusions in this material was such that the need for orthodontic treatment was graded as "strong".

b) *Post-treatment group*

23 patients were taken at random from the Orthodontic Department, Royal Dental School, Malmö, after completion of orthodontic treatment and an occlusal analysis was made of their dentitions (Table I). All patients, except three, K.D., B.Å., and T.Ö., had been without orthodontic appliances for at least 6 months. Their ages ranged from 11 to 17 years, mean age being 14 years. 12 of the patients were examined electromyographically in order to objectively study their muscle activity while performing various movements and positions of the mandible.

## Functional analysis

The masticatory system of each patient was studied according to current principles of occlusal analysis (*Posselt* 1962). Special stress was laid on the assessment of cuspal interferences during closing movements of the mandible (centric interference) and during gliding contact movements (non-working side interference). In terminal hinge movements a slide of the mandible straight forward (about 1 mm) into the intercuspal position was not considered an abnormal condition.

"Centric relation" was registered by gently guiding the mandible up and down in a hinge-like movement but without forcing the jaw back strongly. After these movements the upper and lower teeth were made to make light contact (in the retruded contact position).

Interfering cusps were detected clinically by means of Kerr Occlusal Indicator Wax or Alginate rolls. In cases of severe cuspal interferences and complicated adjustments, casts were mounted on an adjustable articulator (Dentatus) and grinding was planned on the casts prior to the adjustment in the mouth.

### Occlusal adjustment by grinding

When occlusal interferences were diagnosed in the post-treatment group, selective grinding was carried out, so that bilateral occlusal contact was obtained in the retruded contact position. Interferences on the non-working side during gliding contact movements were eliminated in each case, and a moderate distribution of stress was obtained on the working side.

Slight purely sagittal (symmetric) shift of the mandible from retruded contact into intercuspal position was not corrected. Only an asymmetric shift between retruded and intercuspal positions was regarded as "interference in centric", demanding a correction by grinding.

### EMG recording

The activity of the masseter, temporal, and suprahyoid muscles was recorded electromyographically during various positions and movements of the mandible by means of monopolar surface electrodes.

For comparison of repeated EMG recordings on the same patients, the tabulated EMG-patterns (see page 196) of each session were compared and the repeatability or variability of the EMG-pattern was determined. In this way the treatment results of occlusal adjustment by grinding were analyzed and evaluated in terms of muscle function.

#### *Instrumentation*

An eight channel inkwriting Kaiser electroencephalograph, type E 1000, was used. The skin electrodes were circular lead plates with a diameter of 10 mm. The high and low frequency filters were adjusted for EMG-recording and the instrument gave a flat frequency response between 20—70 cps. The gain of each channel was set so that a calibration signal of 50 microvolt gave a pendeflection of 10 mm. An "all channel switch" was used to reduce the amplification during biting and mastication (200 microvolt = 10 mm). The interelectrode resistance was measured and it was in all cases below 10,000 ohms. The instrument was calibrated before and after each recording.

#### *Electrodes*

Surface electrodes were used in this study for two reasons: they do not cause pain and thus limit inconvenience to the patient, secondly, they are usually satisfactory for determining relative degrees of activity in the muscles being observed (*Basmajian* 1962, *Carlsöö* 1952, *Cuthbert & Denslow* 1945, *Goodgold & Moldaver* 1955, *Hoefer* 1949, *Liebman & Cosenza* 1961, *Moyers* 1950, *Möller* 1958, *Sutton* 1962). Two electrodes were placed over the temporal muscle and one over the masseter muscle on each side. Only the ventral portion of the digastric muscle is available for surface recording, and the electrodes were placed 1 cm behind the gnathion point. Great precautions were taken to reproduce as fairly as possible the electrode positions, when successive recordings on the same patients were performed. The posture of the patient's head was checked and the subjects were instructed to look straight forward on eyelevel. The patient was grounded by a surface electrode attached to the forhead and a "generalized" reference electrode was used (*Hickey et al.* 1958).

At the beginning and end of each experiment the electrical activity of the masticatory muscles was recorded when the subject was as relaxed as possible. The patients were instructed to perform repeated bitings in the intercuspal position (light and heavy contact), lateral and protrusive gliding excursions, and thereafter the muscle coordination during gum-chewing and swallowing was studied.

*Evaluation of recorded action-potentials*

The muscular pattern during various positions and movements of the mandible has been extensively studied by *Moyers* 1950, *Pruzansky* 1952, *Geltzer* 1954, *Carlsöö* 1952, *Greenfield & Wyke* 1956, *Grossman, Greenfield & Timms* 1961, *MacDougal & Andrew* 1953. The swallowing pattern and chewing pattern were investigated by *Pruzansky* 1952, 1960, *Tulley* 1957, *Perry* 1954, 1955, *Kawamura* 1958, *Kilpatrick* 1960, *Ramfjord* 1961, and *Posselt* 1958 a. Their findings and interpretations have been used for comparison with the EMG-patterns in this study. Especially the chewing pattern was analyzed carefully, since we anticipated that the coordination of muscular contraction during gum-chewing was a good guide to evaluate the functional condition of the occlusion and articulation of the teeth.

Since this is mainly a kinesiologic study of mandibular movements and positions, it was considered satisfactory to record patterns of muscular contractions. No attempts were made to quantitate the recorded actionpotentials. It is felt that a qualitative method of EMG-evaluation is more reliable than a self-deceptive semiquantitative basis for determination (*Basmaijan* 1962, *Ralston* 1962). The emg technique in itself especially when inkwriting instruments are used, is still too inaccurate and full of unverifiable influences to justify conclusions based on comparisons of quantitative measurements of amplitude and frequency. Thus, in this study the relative degree of muscular activity and the time-relationship between the various muscle groups were evaluated and used as criteria of normal or abnormal occlusal function. The following characteristics of each contraction-phase were tabulated and formed the pattern of muscular contraction in each prescribed movement.

1. *Amount of electrical activity.* — The amplitude and duration of each contraction was measured and graded in relation to the electrical magnitude of the other contracting muscles *on that particular record.* Since nearly all the muscle contractions were of the "interference-pattern" type no frequency determination was included.

2. *Timing.* — The synchrony of the start, peak and end of contraction was evaluated according to the time-relationship of the muscles on that particular occasion.

3. *Form of contraction-phase.* — The contraction-cycle was evaluated regarding complexity in form and appearance (one-peaked, two-peaked and multi-peaked contractions). In order to facilitate a general survey and a more accurate evaluation of the EMG-pattern, the circumference of each contraction phase on the EMG, as well as the parallel time lines, were drawn on transparent paper. From these graphs the amount of activity and synchronization was determined.

## RESULTS

The results of this study are summarized in Tables II—VII.

*Pre-treatment group* (120 children in need of orhodontic treatment). Table II and Figs. 1 and 2 illustrate the distribution of cuspal interferences in a group of children having various types of morphologic malocclusion. It can be seen that 55 per cent of these 120 children have cuspal interferences that are considered severe (asymmetric "slide" in centric relation and/or interferences on the non-working side). The distribution according to

**Table II**

*Incidence of Cuspal Interferences in 120 Children (Age 11—17 Years) according to Type of Malocclusion.*

| Type of malocclusion (Angle) | Number of patients without cuspal interference | Number of patients with cuspal interference | Total | Per cent with cuspal interference |
|---|---|---|---|---|
| Class I | 15 | 26 | 41 | 63 |
| Class II, 1 | 30 | 25 | 55 | 45 |
| Class II, 2 | 5 | 6 | 11 | 55 |
| Class III | 4 | 9 | 13 | 69 |
| Total | 54 | 66 | 120 | 55 |

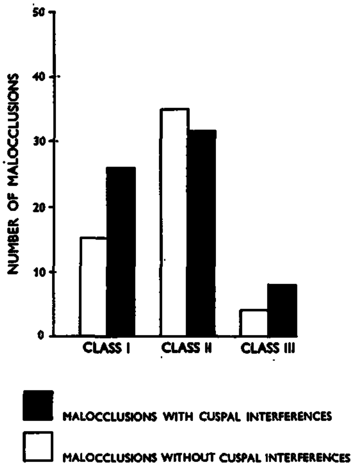


Fig. 1. Number of cases with and without cuspal interferences within the different classes (Angle) of malocclusions in 120 patients prior to orthodontic treatment.

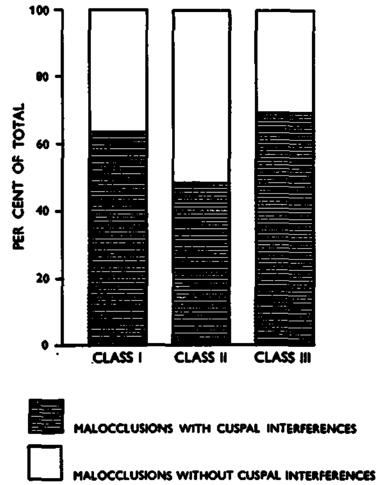


Fig. 2. Proportions of cases with and without cuspal interferences within the different classes (Angle) of malocclusions in 120 patients prior to orthodontic treatment.

type of malocclusion (Angle) is fairly even, although there is a trend in this material that Class I malocclusions are more affected with cuspal interferences than are Class II, Div. 1 malocclusions. The proportion for Class I is 63 per cent (approximately 3 out of 5 patients) and for Class II, Div. 1 malocclusions 45 per cent (approximately 2 out of 5 patients) with cuspal interferences. The Class III and Class II, Div. 2 material is too small to allow any comparison in this respect.

Both types of cuspal interferences considered in the present investigation, *i.e.* the terminal hinge cuspal interference and interference on the non-working side, appear in approximately equal numbers, both totally and within the various classes of malocclusion (Angle). Thus, no specific malocclusion seems to be associated with a specific interference. The distribution of cuspal interferences between the various malocclusions is practically equal to the number of patients within each class of malocclusion, indicating that usually each of the two diagnosed interferences appears separately (Table III).

**Table III**

*Type and Distribution of Cuspal Interferences in a Group of 120 Pre-treatment Orthodontic Patients according to Type of Malocclusion.*

| Type of malocclusion (Angle) | Number of interferences | | |
|---|---|---|---|
| | Non-working side | "Guided hinge closure" | Total |
| Class I (41) | 16 | 16 | 32 |
| Class II, 1 (55) | 16 | 13 | 29 |
| Class II, 2 (11) | 4 | 2 | 6 |
| Class III (13) | 5 | 4 | 9 |
| Total (120) | 41 | 35 | 76 |

If the material is analyzed further regarding the relation between cuspal interferences and crossbite occlusions some interesting findings are noticed (Fig. 3 and Table IV). In the malocclusion group with cuspal interferences the incidence of crossbite

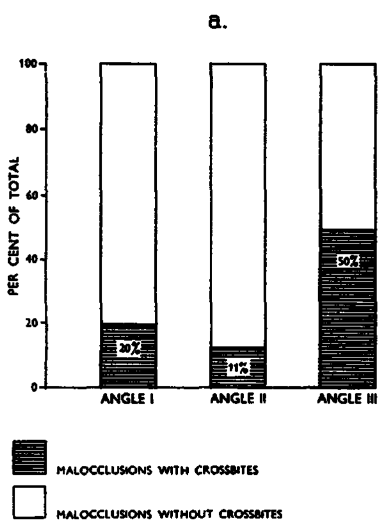


Fig. 3 a. Proportions of cases with and without crossbites in 54 orthodontic patients without cuspal interferences.

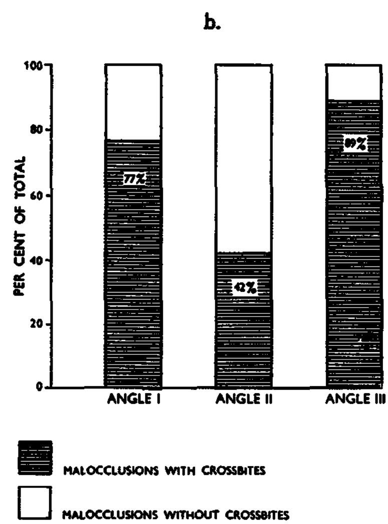


Fig. 3 b. Proportions of cases with and without crossbites in 66 orthodontic patients with cuspal interferences.

**Table IV**

*Type of Crossbites and Distribution according to Class of Malocclusion in 41 Orthodontic Patients with Cuspal Interferences.*

| Classification of malocclusion | Number of crossbites Anterior | Posterior | Total |
|---|---|---|---|
| Angle I | 15 | 13 | 28 |
| Angle II | 1 | 13 | 14 |
| Angle III | 7 | 2 | 9 |
| Total | 23 | 28 | 51 |

occlusions is extremely high in comparison with the group without cuspal interferences. The proportion figures for Angle Class I malocclusions are that 77 per cent have crossbite occlusions in the group, which is diagnosed as having cuspal interferences, and only 20 per cent in the patient group without cuspal interferences. For Class II malocclusions corresponding figures are found: 42 per cent crossbite occlusions in the group with cuspal interferences and 11 per cent in the other group. Thus, in this material the presence of cuspal interferences and crossbite occlusion have a strong relationship. Further it can be seen from Table IV that patients with Angle Class I malocclusions have the largest number of crossbite occlusions. If only the posterior crossbites are counted, Class I and Class II malocclusions have similar numbers.

*Post-treatment group* (23 finished orthodontic patients). — 14 out of the 23 patients had cuspal interferences (Tables I and V). These patients were treated by grinding interfering cusps or surfaces, and then again clinically evaluated after some time.

**Table V**

*Orthodontic Treatment Results (23 Patients) in relation to Cuspal Interferences and the Results of Occlusal Adjustment by Tooth-grinding.*

| Before occlusal adjustment | | After occlusal adjustment | |
|---|---|---|---|
| No. of patients with cuspal interferences[1]) | No. of patients without cuspal interferences | No. of patients with cuspal interferences | No. of patients without cuspal interferences |
| 14 | 9 | 1 | 22 |

[1]) See Table I for a more detailed description.

The results were estimated as good in 13 of the 14 cases which previously had cuspal interferences. Only one case did not respond to the treatment and will be treated by other means.

In order to corroborate the clinical findings of aberrations in mandibular function the muscle contraction patterns of 16 patients in this group were analyzed by the EMG method. It has been claimed previously, that EMG recordings can reveal minute changes in function due to cuspal interferences of the teeth (*Pruzansky* 1960, *Ramfjord* 1961, *Porrit* 1960). The recorded group consisted of 12 patients with cuspal interferences and 4 patients without cuspal interferences. The EMG-patterns during biting into the intercuspal position, swallowing and chewing gum were recorded and tabulated according to the specific method, previously described under "Material and Methods".

The EMG-patterns for the two groups were compared and any aberrations in pattern were noted and analyzed in terms of muscle function (Figs. 4, 5[1]). It appears from Table VI that all cases with cuspal interferences displayed some form of "abnormal" contraction pattern. The swallowing pattern was least sensitive to these cuspal interferences, while the chewing and occlusion patterns were in some way unfavourably affected in most cases. However, the interpretation of these findings in terms of muscle function is difficult, because in the group where no interferences were present the pattern sometimes was different from what is considered "normal". Obviously, it is hard to say whether all deviations of EMG-patterns found in the group with cuspal interferences are caused by the presence of cuspal interferences. Also, we feel that minute changes in mandibular behaviour are difficult to detect by this method, since monopolar surface electrodes pick up activity from such a large area that other muscles may obscure the pattern.

Six of the patients, who had cuspal interferences, were further analyzed electromyographically after the occlusal adjustment (Fig. 6). The tabulated EMG-patterns before and after adjustment by grinding were compared and analyzed. Table VII gives a summary of the results. The contraction pattern in occlusion was improved in four of the six investigated patients and deteriorated in one patient (Fig. 6 a). One patient did not show any

[1]) For all electromyographic records, see appendix at the end of the article.

**Table VI**

*The Relationship between Cuspal Interferences and Aberrations in the EMG-pattern of 12 orthodontically treated Patients during various Mandibular Movements.*

The changes are relative to the EMG-pattern of 4 orthodontically treated Patients without Cuspal Interferences.

(An aberration is marked with X, no change is marked with 0).

| | | Cuspal interferences[1]) | | Aberrations from "normal" EMG-pattern | | | |
|---|---|---|---|---|---|---|---|
| No. | Name | Closing movements | Gliding movements | Occlusion | Swallowing | Chewing left | Chewing right |
| 1 | B.S. | neg. | pos. | 0 | 0 | 0 | X |
| 2 | B.Å. | pos. | pos. | X | X | X | X |
| 3 | D.S. | pos. | pos. | X | X | X | X |
| 4 | K.C. | pos. | neg. | 0 | 0 | X | X |
| 5 | P.A. | pos. | neg. | X | 0[2]) | X | 0 |
| 6 | G.V. | pos. | neg. | X | 0 | 0 | X |
| 7 | G.E. | pos. | neg. | X | 0 | 0 | X |
| 8 | T.Ö. | neg. | pos. | 0 | 0 | X | X |
| 9 | W.C. | pos. | pos. | X | 0 | 0 | X |
| 10 | M.P. | pos. | pos. | X | 0 | X | X |
| 11 | K.D. | pos. | pos. | X | 0[2]) | X | 0 |
| 12 | A.A. | neg. | pos. | X | 0[2]) | 0 | X |

[1]) Positive finding is marked pos., negative finding is marked neg.
[2]) Repeated, voluntary swallowings gave an aberrant pattern.

## Table VII

*Summary of Results of an EMG-analysis of the Contraction-patterns during Biting into the Intercuspal (Habitual) Position, Chewing and Swallowing in six Orthodontic Patients before and after Occlusal Adjustment.*

(Improved pattern = pos., deteriorated pattern = neg., no change = 0)

| Name | Balance of contraction pattern | | | Synchronization of contraction pattern | | | Form of contraction phase | | |
|---|---|---|---|---|---|---|---|---|---|
| | Occlusion | Chewing | Swallowing | Occlusion | Chewing | Swallowing | Occlusion | Chewing | Swallowing |
| G. V. | pos. | pos. | 0 | pos. | pos. | 0 | 0 | 0 | 0 |
| D. S. | neg. | neg. | 0 | neg. | neg. | 0 | 0 | pos. | 0 |
| P. A. | pos. | pos. | 0 | pos. | neg. | 0 | 0 | 0 | 0 |
| B.-Å. | pos. | pos. | 0 | 0 | 0 | 0 | pos. | pos. | 0 |
| B. S. | 0 | pos. | 0 | pos. | 0 | 0 | 0 | pos. | 0 |
| K. C. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | pos. | 0 |

marked changes in muscle pattern. The chewing pattern was improved in three patients (Fig. 6 c, d). In two patients the pattern deteriorated after occlusal adjustment. In one patient the contraction pattern did not change significantly.

No change in the swallowing pattern could be detected with any certainty (Fig. 6 b).

Thus, in terms of recorded muscle contraction patterns the clinically favourable results could not be fully substantiated even though most of the patients exhibited improved muscle patterns. The material, however, is smaller than the one evaluated clinically and, as previously mentioned, it is also possible that monopolar surface electrodes are not adequately selective for recording minor changes in muscle activity.

The above surmise was substantiated by a study of two other subjects where the muscle activity, picked up from the masseter and temporal muscles with monopolar surface electrodes, was checked with simultaneous recordings with unipolar needle electrodes (*Jasper & Ballem* 1949) and bipolar surface electrodes. It was found that monopolar surface recording must be evaluated with great caution, because the electrodes easily pick up surrounding muscle activity, especially that coming from other orofacial muscles, suprahyoid muscles, and tongue muscles (Fig. 7). This is especially evident during swallowing and chewing, where a great participation of these muscle groups is natural (Figs. 7, 8). The masseter leads are far more sensitive than the temporal recordings in this respect. Thus, the method of emg monopolar surface recording seems to be adequate only for recording gross changes in mandibular muscle function. The method seems more reliable when the involvements of the 7th and 12th cranial nerve muscles can be kept under control or reduced, *e.g.* in specifically prescribed movements such as in biting (Fig. 9), opening movements and so on. Recordings with bipolar surface electrodes are more selective and give more reliable results of the muscle pattern.

The recorded action-potentials on the suprahyoid (digastric) channels were not analyzed in detail, because it was considered to be activity coming from unknown origin, and therefore not reliable for a closer analysis. The suprahyoid muscle record was, however, very useful in many ways. In the chewing records, for instance, it indicated the start of the opening movement and it served well to differentiate between biting and swallowing records when any doubt was present. In the swallowing record the suprahyoid channels always displayed strong activity, whereas in biting they were usually without activity.

## DISCUSSION

It is clearly borne out by the present investigation that cuspal interferences (according to the definition used in the present article) are quite common in pre-orthodontic as well as in post-orthodontic cases. The distribution according to type of malocclusion (Angle) is fairly even in the untreated group and, thus there appears to be no relation between a certain morphologic class (Angle) and functional malocclusion. A noticeable fact was, however, the strong connection between crossbite occlusion and cuspal interferences. This has clinical significance because many times a posterior crossbite may be overlooked, because it is relatively harmless from a morphological standpoint. Nevertheless, it may constitute a severe occlusal disharmony. The finding that crossbite occlusions are often connected with muscle incoordination corroborate the clinical findings of *Posselt & Nohrström* (1960).

It was further evident that *gross* incoordination of the temporal and masseter muscles can be detected by emg monopolar surface recordings of the muscle activity during closures into the intercuspal position, chewing (gum) and swallowing. Improvement in the coordination pattern was obtained after occlusal adjustment by grinding in the majority of cases.

Registrations of the chewing pattern proved to be superior to records of the swallowing pattern for evaluating the presence or absence of cuspal interferences in this material. This is probably due to the fact that many children in this investigation did not swallow with their teeth in contact. For this reason the swallowing record firstly was not very useful. Furthermore, synergism is generally present in swallowing even if cuspal interferences are revealed from other movements and emg functional tests.

The rejection of the swallowing test as recorded by EMG is in contrast to the conclusions by *Ramfjord* (1960) who considered the chewing pattern less conclusive than the swallowing pattern. He found that muscle incoordination due to cuspal interferences is revealed clearly by the swallowing pattern.

The divergence in results between the studies may be explained by the fact that children swallow less often with their teeth in contact than adults, who were examined in Ramfjord's study. This interpretation is substantiated by other investigators (*Ward* 1962, *Rogers* 1961) who report up to 75 per cent of visceral swallowers in elementary school children. Other differences in material were that the patients investigated and examined by *Ramfjord* were adult patients with bruxism and temporomandibular joint pain, whereas the patients of this study were much younger and only a minority exhibited symptoms from the joints and muscles.

The investigations indicate the importance of performing functional analysis. Since the occlusion influences the muscles and temporomandibular joints, the importance of function of the masticatory system has to be considered. An orthodontic intervention is hardly justified if the end result is left with functional disturbances, which may later on cause disease or disorder of the stomatognathic system. A morphologic abnormality of the teeth may in this way be substituted by a functional abnormality during mastication and swallowing, which has to be considered a worse condition than the original one. *Moyers* (1955) reports that in 150 cases of temporomandibular joint disturbances approximately 40 per cent had had previous orthodontic treatment.

The question whether casts of the patients should be mounted on the articulator in order to obtain a sufficient degree of correction of cuspal interferences is not investigated systematically in the present work. Various types of selective grinding have not been investigated either. Nor has the long term stability of the occlusion after grinding been investigated in connection with the present study.

The present investigation indicates that occlusal disharmonies are frequently present in orthodontic patients. Since there is some evidence that occlusal disharmonies (especially cuspal interferences) are functionally important during the long range development of the child and the adult dentition, they may be considered an important aspect of malocclusion. Functional malocclusions (cuspal interferences) may even be the most important aspect of malocclusion, disregarding apparent facial defects. If this is true, the need for orthodontic treatment might be limited and evaluated from the standpoint of whether in (morphologic) malocclusions occlusal disharmonies do or do not exist. These hypotheses definitely deserve further investigation.

The reliability of monopolar surface recording was studied by comparing simultaneous records picked up by bipolar surface electrodes and unipolar needle electrodes. Unipolar needle electrodes were used in preference of concentric needle electrodes, because they give less sensation of pain and discomfort. Furthermore, registrations with monopolar and concentric needle electrodes give comparable results (*Goodgold & Moldaver* 1955, *Cuthbert & Denslow* 1945, *Lundervold & Li* 1953).

It is evident from this study that monopolar surface electrodes are not adequately selective for recording minor changes of muscle activity. The pick-up range of surface electrodes is very large and actually one does not exactly know from where the recorded action potentials come. This is especially true for the masseter electrodes, which promptly record activity from cheek, lip and tongue musculature. The temporal recording is more reliable, because there is no interfering underlying muscle tissue.

The bipolar surface recording gave more reliable registrations of muscle activity than did the monopolar surface recording. This has also previously been proved by other authors (*Möller* 1960, *Latif* 1957). It is hardly possible to find an "indifferent" point on the body for the comparative electrode used in monopolar recording.

## SUMMARY AND CONCLUSIONS

Various reports in the literature give evidence that cuspal interferences and other occlusal disharmonies may cause pathologic changes in the masticatory system. It is conceivable that malocclusions in a morphologic sense more frequently exhibit occlusal disharmonies (functional malocclusion) than occlusions which are morphologically normal, but nothing exact is known about this. Being based on morphologic criteria, current classifications of malocclusion give no information regarding this matter.

The present investigation deals with the following problems:

(1) The occurrence of occlusal disharmonies before and after orthodontic treatment.

(2) The possible connection between morphological malocclusion and functional malocclusion.

(3) The possibility of using the electromyographically recorded muscle pattern in determining the presence or absence of occlusal interferences.

(4) The effect of occlusal adjustment through selective grinding in cases with occlusal disharmonies.

120 untreated patients were examined according to current principles of functional analysis. The age range was 7 to 15 years, mean age 11 years.

23 patients, aged 11—17 years, mean age 14 years, who had undergone orthodontic treatment were also examined functionally. In the cases where a movement of the mandible from the retruded position into the intercuspal position was found to be accompanied by a lateral shift, selective grinding was carried out. Selective grinding was also carried out in cases where cusp interferences on the non-working side (gliding movements) were diagnosed. The latter patients were also examined electromyographically while performing various positions and movements of the mandible. In particular the chewing and swallowing patterns were investigated.

The present investigation showed (Tables II—VII) that cuspal interferences occurred in 55 per cent of the untreated patients.

In no specific class of malocclusion (Angle) occurred cuspal interferences particularly often. However, they did occur more often in cases of crossbite occlusion as compared to other types of morphologic malocclusion.

Out of the 23 orthodontically treated cases cuspal interferences were present in 14 cases (61 per cent). 13 of these patients were treated successfully with regard to the occlusal disharmonies by occlusal adjustment (selective grinding).

Poor synergy of the recorded muscles while chewing, swallowing and performing biting movements into the intercuspal position was found in all patients with cuspal interferences. The swallowing pattern was least affected in this respect. 6 patients with cuspal interferences were analyzed electromyographically before and after occlusal adjustment. The contraction pattern had improved in the majority of cases.

The electromyographic technique with monopolar surface recording was tested against other recording methods of muscle action-potentials. The result of this test is discussed.

### *Conclusions*

(1) Cuspal interferences as a complicating factor in malocclusion of the teeth are common.

(2) No particular type of malocclusion according to Angle's classification system seems associated with cuspal interferences.

(3) Among the various morphologic types of malocclusion cross-bite occlusion shows cuspal interferences most frequently.

(4) From the clinical and electromyographic evidences of this study it must be considered important to check orthodontic end results for cuspal interferences and, if possible, to correct them through occlusal grinding.

(5) The electromyographic pattern during gum-chewing is a valuable diagnostic aid in evaluating functional abnormalities in the young dentition.


## RÉSUMÉ

### NECESSITÉ D'UNE ANALYSE FONCTIONNELLE ET ACTION DE LA RECTIFICATION DE L'OCCLUSION APRÈS TRAITEMENT ORTHODONTIQUE

### ÉTUDE CLINIQUE ET ÉLECTROMYOGRAPHIQUE

Il ressort de ce qui a été écrit à ce sujet que les interférences des cuspides peuvent causer des symptômes dans les muscles et l'articulation temporomandibulaire, et apporter des modifications dans d'autres parties du système de mastication.

Vu que les discordances de l'occlusion ainsi que les anomalies et troubles fonctionnels ne peuvent être diagnostiqués que par un examen fonctionnel du système de mastication, aucun système courant de classification des malocclusions dentaires utilisé en orthodontie ne peut donner ce genre d'information. On peut imaginer que les malocclusions de nature morphologique, révèlent

plus souvent des discordances de l'occlusion que les occlusions morphologiquement normales, mais on ne possède aucun renseignement exact à ce sujet.

Les problèmes traités dans l'étude présentée ici sont les suivants:

1) La présence de discordances de l'occlusion avant et après un traitement orthodontique.
2) La possibilité d'un rapport réciproque entre la malocclusion morphologique et la malocclusion fonctionnelle.
3) Le schème de contraction du muscle enregistré à l'électromyographe peut-il être utilisé pour déceler la présence ou l'absence d'interférences des cuspides?
4) L'effet des ajustements de l'occlusion opérés par le meulage selectif sur le schème de contraction des muscles, dans les cas de discordance de l'occlusion.

120 sujets non-traités ont été examinés par analyse fonctionnelle. Ils avaient entre 7 et 15 ans, l'âge moyen étant de 11 ans.

23 sujets, de 11 à 17 ans, l'âge moyen du groupe étant de 14 ans, qui avaient subi un traitement orthodontique ont également été examinés au point de vue fonctionnel. Dans les cas où l'on a constaté des déviations latérales au passage de la position de retrait à la position d'intercuspidation, et ceux où des interférences des cuspides sur le côté non-actif ont été diagnostiquées, on a soumis ces sujets à un traitement par le meulage sélectif.

Cette dernière catégorie de sujets a été également examinée à l'électromyographe dans diverses positions et mouvements de la mandibule; en particulier, les schèmes qui se produisent à la mastication et à la déglutition ont été étudiés.

Les résultats (Planches II—VII) ont révélé que parmi les éléments non-traités, 55 pour cent présentaient des interférences des cuspides.

Aucune classe spécifique de malocclusion (Angle) n'a présenté des interférences des cuspides particulièrement fréquentes. Cependant, les articulés croisés[1]) ont paru beaucoup plus affectées par les interférences des cuspides que les autres types de malocclusion morphologique.

Dans le groupe qui avait subi un traitement orthodontique, 61

[1]) Les occlusions contenant des inversions des rapport normaux situés à la région premolaires-molaires.

pour cent ont révélé la présence d'interférences des cuspides. Ces discordances de l'occlusion ont été rectifiées dans une proportion de presque 100 pour cent à la suite d'un ajustement par meulage selectif.

Tous les sujets ayant des interférences des cuspides ont manifesté un faible degré de synergie des muscles enregistrés au cours des mouvements de mastication, de déglutition et lors de l'occlusion en position d'intercuspidation. Il est apparu le schème enregistré à la déglutition était le moins affecté de tous à cet égard. Six sujets présentant des interférences des cuspides ont été analysés à l'électromyographe avant et après l'ajustement de l'occlusion. Le schème de contraction s'est trouvé améliore après traitement dans la majorité des cas.

La technique electromyographique — son enregistrement monopolaire en surface — est comparée à d'autres méthodes d'enregistrement des potentiels d'action musculaire. Cette question est discutée dans sa connexion avec l'enregistrement des activités musculaires de la mâchoire.

## *Conclusions*

1. Les interférences des cuspides constituent un facteur de complication courant dans les cas de malocclusion.
2. Aucun type particulier de malocclusion prévu dans le système de classification d'Angle ne semble associé aux interférences des cuspides.
3. Les articulés croisés semblent être le type morphologique de malocclusion qui s'accompagne le plus fréquemment d'interférences des cuspides.
4. En partant des constatations cliniques et électromyographiques relevées dans cette étude, il semble essentiel de contrôler les résultats orthodontiques finaux en matière d'interférences des cuspides et, si possible, de les corriger par le meulage selectif.
5. Le schème electromyographique manifesté à la mastication de "chewing-gum" est d'un grand secours lorsqu'il s'agit d'évaluer les anomalies fonctionnelles de la dentition des jeunes.

## ZUSAMMENFASSUNG

### DIE NOTWENDIGKEIT DER FUNKTIONELLEN ANALYSE UND DER EFFEKT DES EINSCHLEIFENS NACH KIEFERORTHOPÄDISCHER BEHANDLUNG

### EINE KLINISCHE UND ELEKTROMYOGRAPHISCHE UNTERSUCHUNG

Aus dem Schrifttum ist ersichtlich, dass Höckerinterferenzen und andere Okklusionsdisharmonien zu Symptomen in Muskeln und Kiefergelenk sowie zu Veränderungen in anderen Teilen des Kausystems führen können.

Es ist anzunehmen, dass Malokklusionen im morphologischen Sinne häufiger mit Okklusionsdisharmonien (funktionelle Malokklusion) verbunden sind als morphologisch normale Okklusionen. Genaues darüber weiss man aber nicht.

Die vorliegenden Untersuchungen haben folgende Fragen behandelt:

1) Das Auftreten von Okklusionsdisharmonien vor und nach orthodontischer Behandlung;
2) einen möglichen Zusammenhang zwischen morphologischer und funktioneller Malokklusion;
3) lässt sich die auf elektromyographischem Wege erhaltene Registrierung der Muskelaktivität dazu benutzen, das Vorhandensein oder Nicht-Vorhandensein von Höckerinterferenzen nachzuweisen?
4) Die Wirkung des Einschleifens auf das Kontraktionsmuster in Fällen mit Okklusionsdisharmonien.

Zur Untersuchung durch Funktionsanalyse gelangten 120 nicht vorbehandelte Personen im Alter von 7—15 Jahren (Durchschnittsalter 11 Jahre).

In gleicher Weise untersucht wurden 23 Patienten im Alter von 11—17 Jahren (Durchschnittsalter 14 Jahre), denen vorher orthodontische Behandlung erteilt worden war. Zeigte sich Lateralverlegung aus der retrudierten Unterkieferlage zur Interkuspidationslage und/oder Höckerinterferenz auf der nicht-arbeitenden Seite, so wurde bei solchen Patienten selektives Einschleifen durchgeführt. Ausserdem wurden sie elektromyographisch bei verschiedenen Lagen und Bewegungen des Unterkiefers untersucht, ganz besonders im Hinblick auf die Erscheinungen beim Kauen und Schlucken.

Die Befunde sind in den Tabellen II—VII aufgeführt. Es geht daraus hervor, dass Höckerinterferenzen bei 55 % der vorher nicht behandelten Fällen bestanden.

Die Fälle mit Höckerinterferenzen waren in Beziehung auf die Malokklusionsklassen nach Angle eben verteilt. Wo die Malokklusionen mit seitlichen Kreuzbiss verbunden waren, kamen aber Höckerinterferenzen verhältnissmässig viel häufiger vor.

Innerhalb der orthodontisch behandelten Gruppe zeigten sich bei 61 % Höckerinterferenzen.

Bei fast 100 % war die Behandlung, bestehend in Einschleifen, erfolgreich.

Alle Personen, bei denen Höckerinterferenzen vorlagen, wiesen ein schlechtes Zusammenwirken der Muskeln während des Kauens und Schluckens sowie beim Zusammenbeissen in der Interkuspidationslage auf. Der Verlauf des Schluckens war in dieser Beziehung am wenigsten beeinflusst. Bei 6 der Patienten mit Höckerinterferenzen wurde vor und nach dem Einschleifen eine elektromyographische Analyse ausgeführt. In der Mehrzahl der Fälle trat eine Besserung der Kontraktionsmuster ein.

Die Technik der Elektromyographie mit monopolaren Oberflächenelektroden wird einem Vergleich gegenüber anderen Methoden zur Aufzeichnung des Muskelarbeitspotentiale unterzogen.

### *Schlussfolgerungen*

1. Höckerinterferenzen bilden einen gewöhnlichen, erschwerenden Faktor bei Malokklusionen des Gebisses.
2. Es scheint keinen besonderen Typ unter den Malokklusionen (Klassifikation nach Angle) zu geben, der prädisponierend für die Entwicklung von Höckerinterferenzen wäre.
3. Seitlicher Kreuzbiss stellt diejenige morphologische Malokklusion dar, die am häufigsten mit Höckerinterferenzen verbunden ist.
4. Die klinischen und die elektromyographischen Befunde der vorliegenden Untersuchungen zeigen, wie wichtig es ist, dass orthodontische Ergebnisse eine Nachprüfung betreffend das Vorhandensein von Höckerinterferenzen erfahren, so dass diese, wenn möglich, durch Schleifmassnahmen gebessert werden.

5. Die während des Gummikauens elektromyographisch erhaltene Aufzeichnung ist eine hoch zu schätzende diagnostische Hilfe bei der Bewertung von Funktionsfehlern in jugendlichen Gebissen.

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(See Appendix on page 218)

# APPENDIX

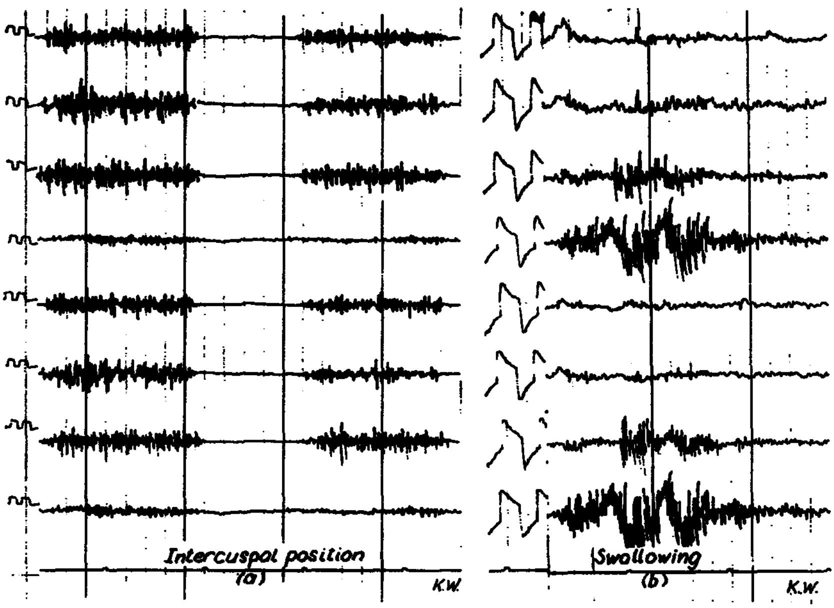



Fig. 4 a and b. Electromyographic records of temporal, masseter and digastric muscles in a subject with good occlusion during (a) Bitings in the intercuspal position and (b) Swallowing. The records represent (from top to bottom) left anterior, posterior temporal, masseter and digastric muscles, right anterior, posterior temporal, masseter and digastric muscles. Calibration-signal = 50 microvolts. Paper-speed = 30 mm/sec.

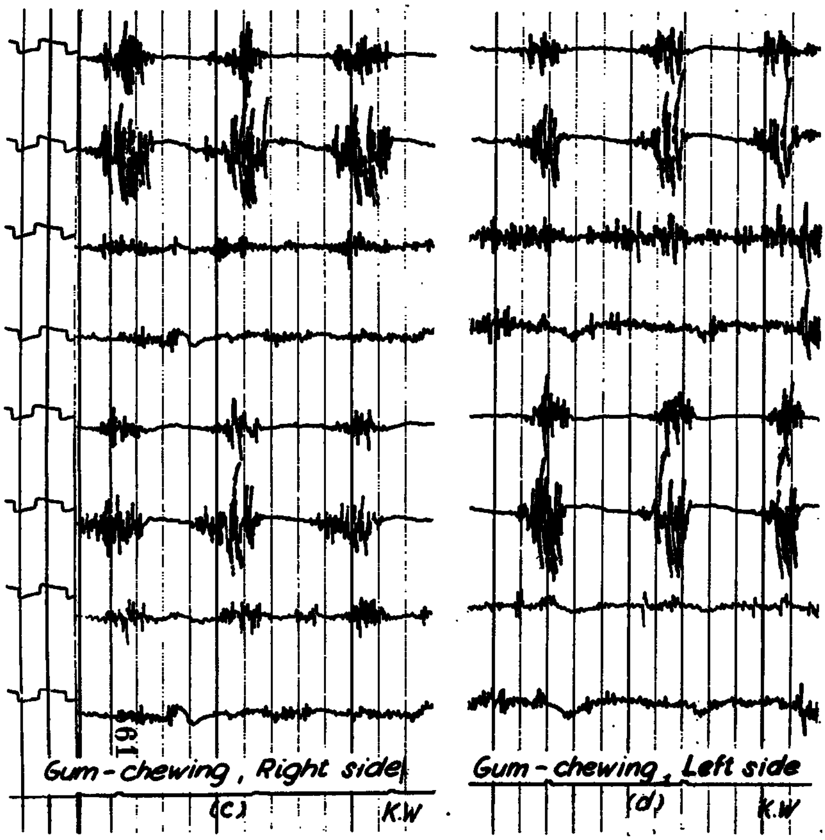



Fig. 4 c and d. Electromyographic records of temporal, masseter and digastric muscles in a subject with good occlusion during c) Gum-chewing right side, (d) Gum-chewing left side. The records represent (from top to bottom) left anterior, posterior temporal, masseter and digastric muscles, right anterior, posterior temporal, masseter and digastric muscles. Calibration-signal = 50 microvolts. Paper-speed = 30 mm/sec.

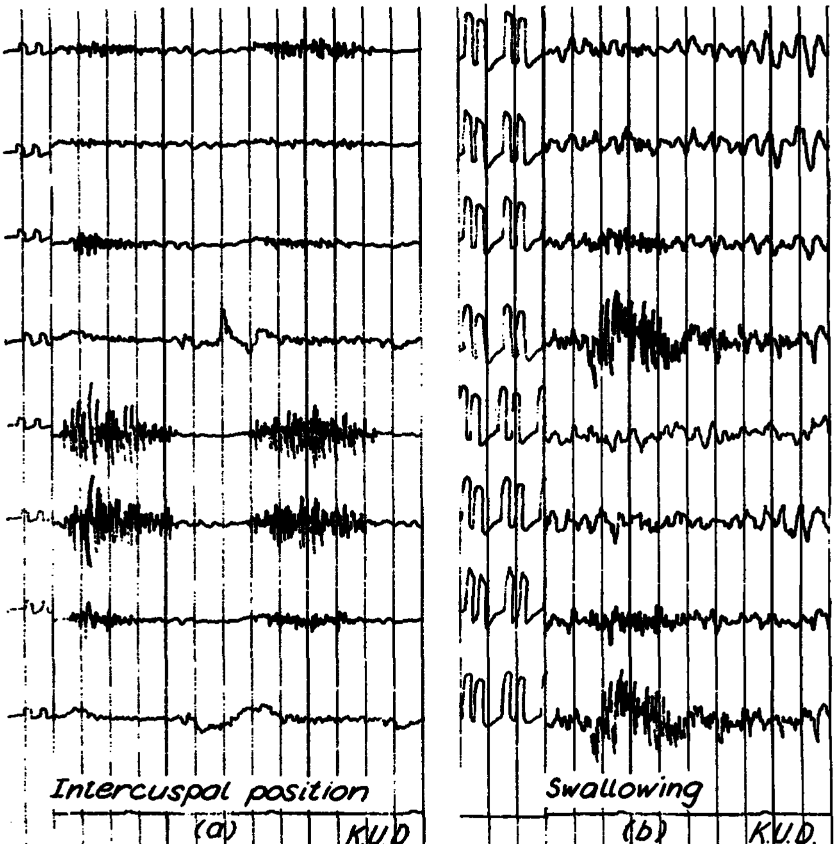



Fig. 5 and b. Electromyographic records of temporal, masseter and digastric muscles in a subject with occlusal disharmonies during (a) Bitings in the intercuspal position and (b) Swallowing. The records represent (from top to bottom) left anterior, posterior temporal, masseter and digastric muscles, right anterior, posterior temporal, masseter and digastric muscles. Calibration-signal = 50 microvolts. Paper-speed = 30 mm/sec.

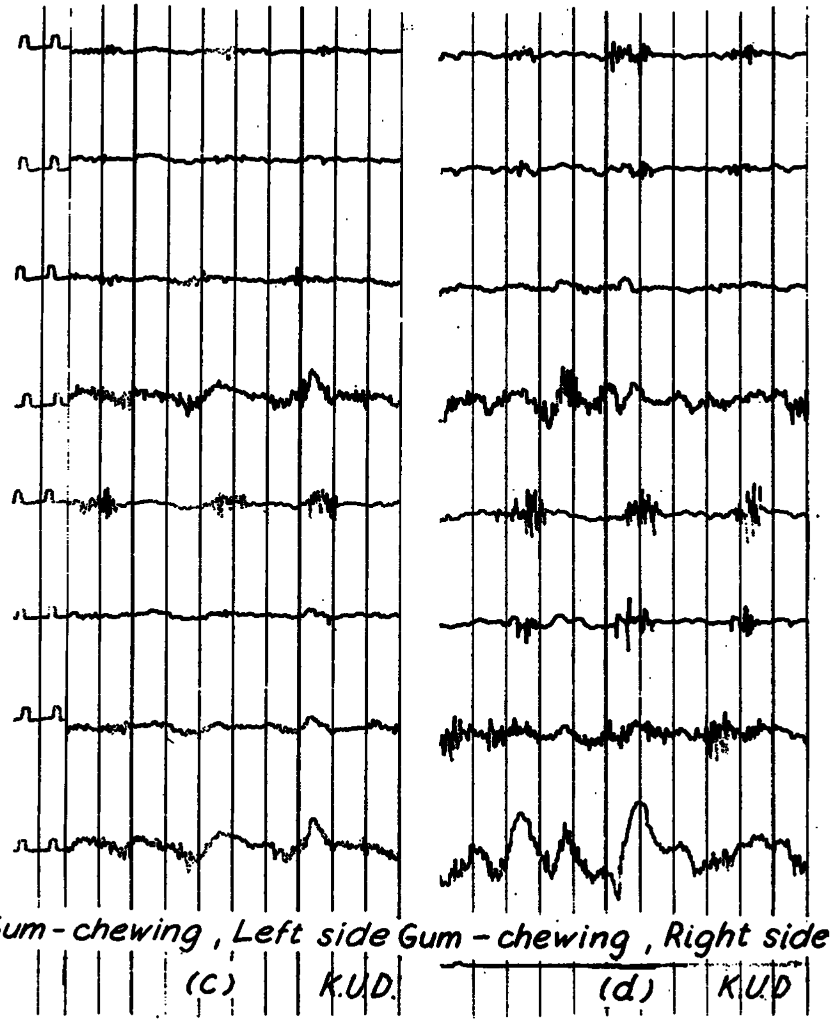



Fig. 5 c and d. Electromyographic records of temporal, masseter and digastric muscles in a subject with occlusal disharmonies during (c) Gum-chewing left side, (d) Gum-chewing right side. The records represent (from top to bottom) left anterior, posterior temporal, masseter and digastric muscles, right anterior, posterior temporal, masseter and digastric muscles. Calibration-signal = 50 microvolts. Paper-speed = 30 mm/sec.

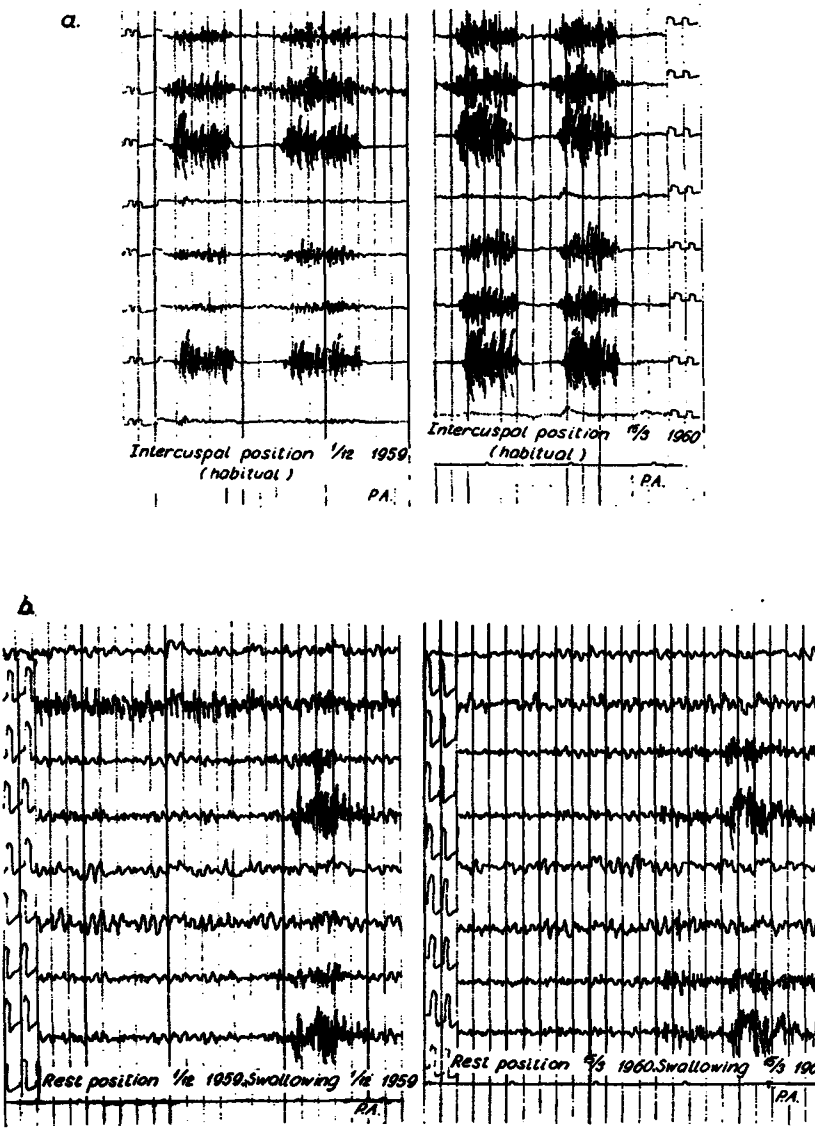
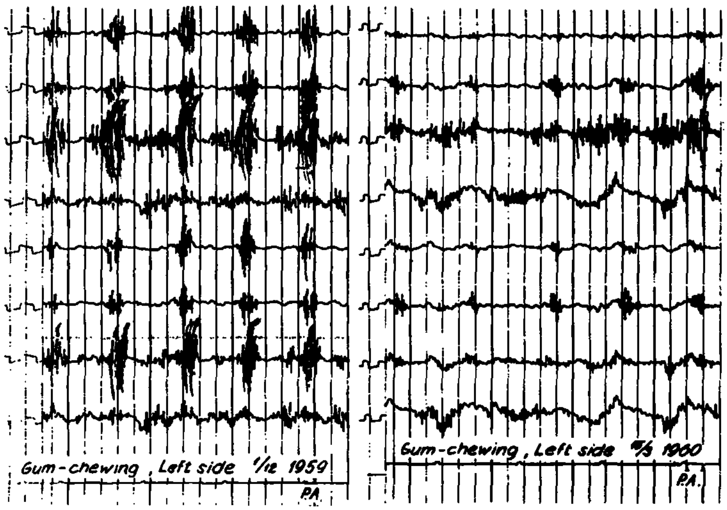



Fig. 6. a och b. Electromyographic records of temporal, masseter and digastric muscles before and after occlusal adjustment by grinding (a) Intercuspal position, (b) Rest position and during swallowing. The records represent (from top to bottom) left anterior, posterior temporal, masseter and digastric muscles, right anterior, posterior temporal, masseter and digastric muscles. Calibration-signal = 50 microvolts. Paper-speed = 30 mm/sec.

c.




d.

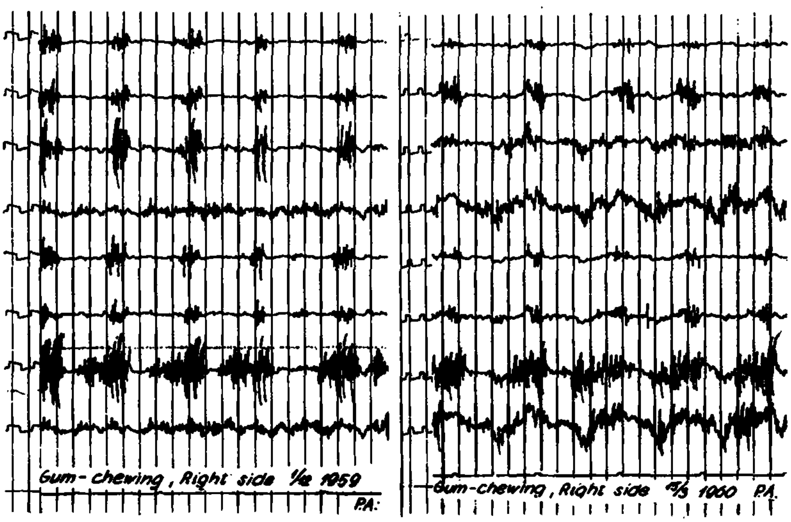



Fig. 6 c and d. Electromyographic records of temporal, masseter and digastric muscles before and after occlusal adjustment by grinding (c) During gum-chewing left side, (d) During gum-chewing right side. The records represent (from top to bottom) left anterior, posterior temporal, masseter and digastric muscles, right anterior, posterior temporal, masseter and digastric muscles. Calibration-signal = 50 microvolts. Paper-speed = 30 mm/sec.

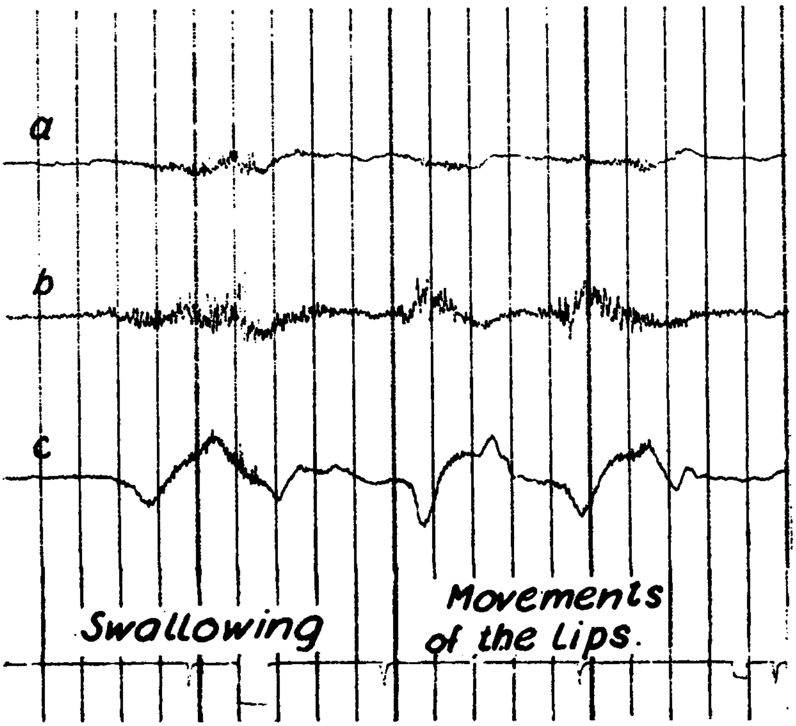



Fig. 7. Electromyographic records of the masseter muscles during swallowing and movements of the lips. The records represent from top to bottom (a) Bipolar surface electrodes, (b) Monopolar surface electrodes, (c) Bipolar needle electrodes. Amplification 10 mm = 200 microvolts. Time-constant 0.1 sec. Paper speed = 30 mm/sec.

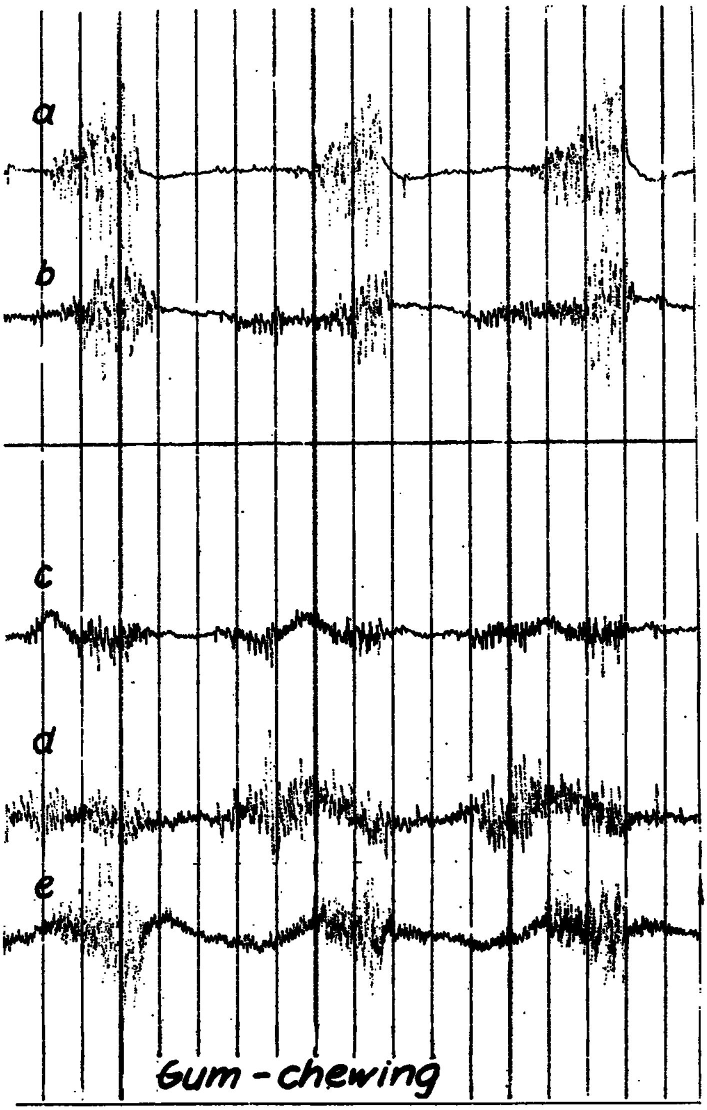



Fig. 8. Electromyographic records of right temporal and masseter muscles during gum-chewing. (a) Bipolar surface electrodes (temporal), (b) Bipolar surface electrodes (masseter), (c) Bipolar needle electrodes (masseter), (d) Monopolar surface electrodes (masseter), (e) Monopolar surface electrodes (temporal). Amplification 10 mm = 100 microvolts. Time-constant 0.1 sec. Paper-speed = 30 mm/sec.

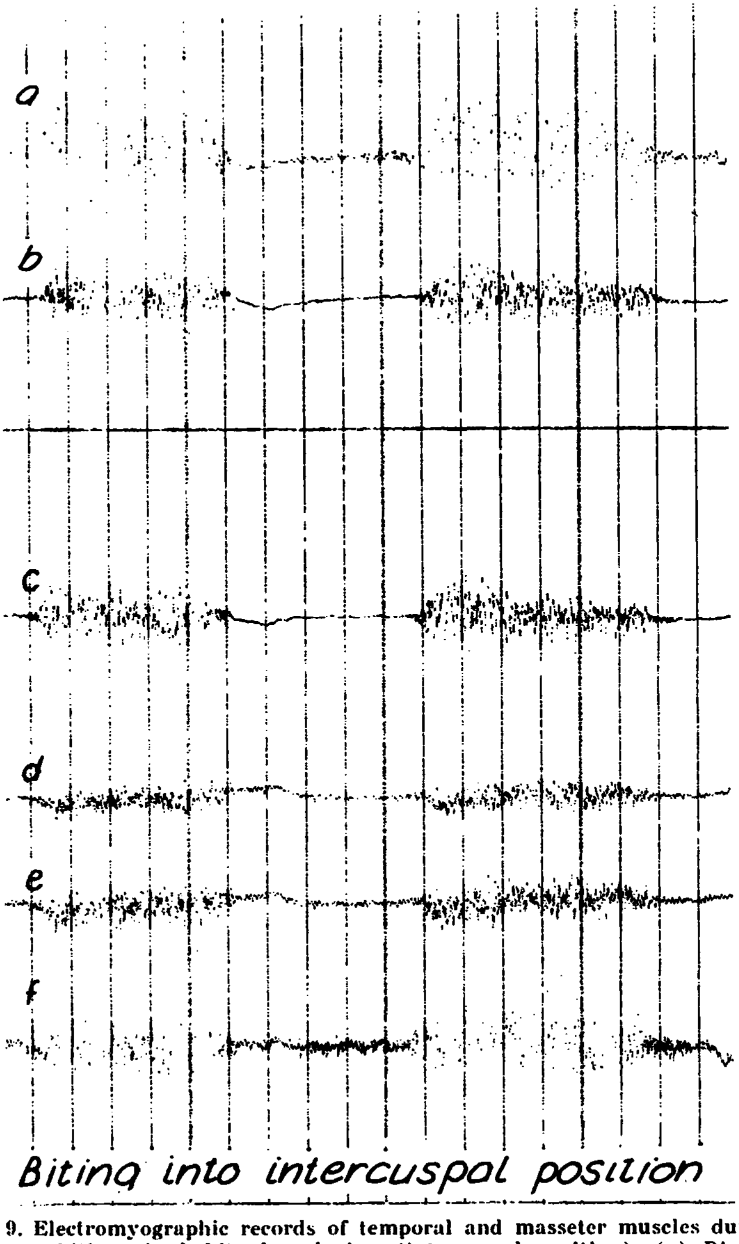



Fig. 9. Electromyographic records of temporal and masseter muscles during repeated bitings in habitual occlusion (intercuspal position). (a) Bipolar surface electrodes (temporalis), (b) Bipolar surface electrodes (masseter), (c) Bipolar needle electrodes (masseter), (d) Monopolar surface electrodes (masseter), (e) Monopolar needle electrodes (masseter), (f) Monopolar surface electrodes (temporalis). Amplification 10 mm = 200 microvolts. Time-constant 0.1 sec. Paper-speed = 30 mm/sec.