The mentalis muscle and postural vertical dimension.

By

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STATEMENT OF AUTHORSHIP

I declared that all works submitted in this thesis is my own, unless otherwise stated. The work of other colleagues is recognized in the Acknowledgements and specifically within the body of the text, wherever appropriate.

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ABBREVIATIONS

Electromyography	EMG
Intercuspal position	IP
Interocclusal distance	IOD
Occlusal vertical dimension	OVD
Postural jaw position/ postural position	PJP/ PP
Postural vertical dimension	PVD
Root mean square	RMS
Statistical package for the social sciences	SPSS
Transcutaneous electrical stimulation	TENS
Visual analogue scale	VAS

ABSTRACT

Introduction

The evaluation and determination of occlusal vertical dimension (OVD) has been considered an important procedure in restorative dentistry, especially when a clinically acceptable new OVD is required prior to commencing a dental treatment. Various methods have been utilized for many decades to establish the OVD, although there is no single method has been agreed on to determine this measurement.

The postural jaw position (PJP) has been used as a starting point to achieve an acceptable OVD by many clinicians. To establish PJP, most clinicians tend to utilize more than one method. Since the mentalis muscle influences the position of the lower lip, examining the visual changes of the mentalis muscle in combination with conventional methods (swallowing and phonetics) would be a useful method to establish the PJP. This study examined changes of the mentalis muscle with increasing facial vertical dimensions which were quantified electromyographically as muscle activity and assessed by different clinicians from clinical photographs.

Aims

This study investigated the mentalis muscle activity electromyographically with varying facial vertical dimensions from the PJP determined clinically, and compared with visual observations of the tension of the mentalis muscle by different clinicians from clinical photographs taken at the same time as the EMG recordings in dentate subjects.

Materials and Methods

This study was carried out with twenty subjects (7 men and 13 women, age range: 23-67 years), who had a sufficient number of teeth to allow stable occlusion. None of the subjects reported any signs and symptoms of temporomandibular disorders. During the experiment, the subjects were asked to complete a VAS with regard to any pain, stress, or anxiety at the end of each trial. EMG activities of the mentalis muscle on varying vertical dimensions (PP without a splint, PP with a splint, PP + 2, +4, +6mm) were recorded according to the protocols. Paired T-test with Bonferroni correction was used to test the statistical significance of EMG activity between the different vertical dimensions. At each trial of EMG recording, clinical photographs were taken to present to the clinicians to assess the photographs. Inter-rater reliability was tested by using Cronbach's alpha.

Results

VAS scores: VAS scores completed by most of the subjects were considered negligible to influence the EMG recordings of the mentalis muscle.

EMG recordings: The difference of mentalis muscle activity between the postural position with and without a splint was statistically significant with 95% confidence. Amongst the positions with a splint, the mentalis muscle activity increased gradually with increased vertical dimensions and Paired T-test showed that there are significant differences in EMG activities of the mentalis muscle between the positions.

Clinical photographic analysis: Assessments of each subject were performed by 3 different clinicians. The percentages of correct assessments were 49%, 49%, and 37% respectively. The frequency of correct assessments for each vertical dimension was analysed for an individual clinicians. Overall, clinicians A and B demonstrated similar rating outcomes compared to clinician C. Cronbach' alpha used to test inter-rater reliability was much lower than the widely-accepted cut off point (0.7).

Discussion

This study was designed to evaluate the efficacy of observation of changes in the mentalis muscle on the varying the PJPs, and two methods of assessments were investigated. The first method was to visually evaluate through clinical photographs, and the second method was to determine any increase in mentalis muscle activity in relation to increases in vertical dimension. The effect of the splint was investigated before comparing EMG recordings on the mentalis muscle at increased vertical dimensions from clinically determined PVD. There were significant differences in EMG on the mentalis muscle between postural position with and without a splint. Although the splint was trimmed to minimize any discomfort, placing a splint in the mouth could stimulate the spindles in jaw muscles, or receptors of the temporomandibular joint. Another possible reason for the significant differences is any errors involved when transferring and increasing IOD on the articulator using an arbitrary hinge axis, which could change a jaw position and influence the mentalis muscle activity. The mean value of EMG activity from the mentalis muscle showed that the activity increased subsequently from PP without a splint, with a splint, +2, +4, and +6mm. In this current study, the mentalis muscle has a specific vertical dimension of minimum muscle activity of each subject, which is PVD.

The observation of changes in chin contour and tension of the skin are clinically useful signs when deciding whether the lips are artificially pulled from the determined PVD. However, an overall view of the observations by 3raters indicates visual methods used to detect the changes are not reliable. This difficulty can be arising from gender, race, facial form, skin tone, and lip competency of the subjects.

Conclusions

In this current study, the mentalis muscle activity increased subsequently from postural position (PP) without the splint, PP with a splint, PP+2, +4, and +6mm. The difference in the mentalis muscle activity between the positions was statistically significant.

Assessing the clinical photographs to identify difference in vertical dimensions by 3 clinicians with different clinical experience levels was not a valid method within this study.

INTRODUCTION

The evaluation and determination of occlusal vertical dimension (OVD) has been considered a critical procedure in restorative dentistry. The OVD is the length of the face when the teeth are in contact. When occlusal contacts between the maxillary and mandibular teeth are unstable or inadequate, it is the clinician's decision to establish a correct and acceptable OVD.

Various methods have been used to establish the OVD. They include the use of pre-extraction records (Zarb et al 1990) such as casts of the teeth in occlusion, profile radiographs, and photographs.

Bissasu (2004) reviewed the efficacy of pre-extraction records for determining the OVD, recording centric relation, and arranging the maxillary anterior teeth. The author concluded that utilizing pre-extraction records to determine the original OVD and arrange the maxillary teeth for a completely edentulous patient were useful and preferred to arbitrary methods.

The other methods utilized to determine the OVD are phonetics (Gillis 1941, Swerdlow 1965, Shirinian 1977, Pound 1978, Rivera-Morales, Silverman 2001), aesthetics-use of soft-tissue facial contour and tone (Zarb et al 1990, Mohindra 2002), swallowing (Niswonger 1934, Vierheller 1968, Preti 1992, Mohindra 1996), cephalometrics (Potgieter 1983, Orthlieb 2000) , craniometrics (Chou 1994, Delic 2002) and EMG (Shpuntoff 1955, Jarabak 1957, Garnick 1962, Feldman 1978, Manns et al 1981, Rugh 1982), although no precise scientific method has been agreed upon to determine this measurement.

However, when selecting the best method to use, accuracy and repeatability of the measurement, adaptability of the technique, type and complexity of the equipment and the length of time required for measurement should be considered (Toolson 1982). Many clinicians use the physiologic "rest" position or postural jaw position as a starting point in clinical assessment and treatment planning.

The definition of postural jaw position has been ambiguous in literatures. Klineberg (1991) pointed out that although postural position is frequently termed "rest position", the jaw position is different when a subject is in relaxed posture, and truly resting posture due to progressive reduction in muscle excitation. Klineberg (2004) defined "postural jaw position (PJP) as the jaw position defined by the jaw muscles when the subject is standing or sitting upright, with variable space between the teeth". The difference between the OVD and postural vertical dimension (PVD) is called "interocclusal distance (IOD) or freeway space" and it usually ranges 1-3mm. However, The glossary of Prosthodontic terms (2005) defined the physiologic "rest" position as the mandibular position assumed when the head is in an upright position and the involved muscles, particularly the jaw elevator and depressor groups, are in equilibrium in tonic contraction, and the condyles are in a neutral, and unstrained position.

Nairn (1965) utilized physiologic "rest" position or postural jaw position to determine the OVD, although this position may be influenced by the length of the masticatory muscles, the rest position of the tongue, the need for a comfortable resting position for the facial muscles, or need for a mandibular position that permits the tongue to be easily elevated against the palate during swallowing. He advocated that it is essential to develop the OVD that is less than PVD by 3mm, which is called IOD or freeway space. The PJP is used as a reference point for profile analysis in prosthodontics and orthodontics along with cephalometric assessments, and also used to determine OVD in combination with IOD.

Atwood (1965) listed the advantages and disadvantages of the various cephalometric techniques to measure the vertical distance while the mandible is at rest. Various clinical measurements using soft tissue landmarks are hindered by a mobility of landmarks, by interference with the "rest" jaw position of the patient, with the attention of the dentist at the time of the measurement, and by the absence of a permanent, continuous record. The use of the roentgenographic cephalometric technique is limited by its need for special equipment, although it is highly accurate, and reproducible. Electromyography (EMG), the recording of muscle activity, was used to study the tonus of masticatory muscles while they are in a postural position, but this method does not measure the vertical dimension between the jaws.

The mechanism of postural jaw position has been unclear, although three explanations have been suggested based on muscle tone, myotatic reflexes, and gravity- elasticity. The muscle tone theory maintains that the postural jaw position is the result of the balance of the tonic state of jaw muscles, and it is termed as postural tonicity. (Moyers 1950).Otherwise, Kawamura (1969) stated that proprioceptive mechanisms in the jaw muscles are highly developed, and information about muscle tension and or length is readily transmitted from muscle proprioceptors to the central nervous system. Both the position of the mandible and maintenance of freeway, or speaking space are controlled by proprioceptive feedback from jaw muscles.

The positional sense of postural jaw position, kinaesthesis (Klineberg 1991) is finely monitored by the proprioceptive reflexes from joints, muscles, periodontal ligaments and oral mucosa. The gravity- elasticity theory of Yemm and Berry (1969) states that mandibular posture may be maintained by passive internal and external forces governed by gravity and the elastic forces associated with the elevator muscles and associated tissues.

Thompson (1946) reported on the cephalometric analysis of "rest" (as described in earlier studies) position in edentulous adults with the time interval from a few days to four years. The author confirmed his belief that the "rest" position was stable and that it could not be permanently altered by prosthetic restorations. He concluded that it has been shown that the mandible assumes its positional relationship to the head by the third month of life and thereafter does not change.

However, it has been shown that postural jaw position will vary according to changes in head position (Mohl 1976), emotional state (Perry 1960), presence or absence of teeth (Tallgren 1957), loss of teeth (Atwood 1958), and the time of recording.

Samant et al (1982) stated that any conditions that can alter the tonicity of the muscles such as bruxism, mouth breathing, and fatigue influence body posture and jaw position. They also cited some significant facial landmarks used to determine the vertical dimension of the face and muscle tone. These landmarks are 1) the turbercle of the upper lip and midline, 2) the clearly defined border of the lip, 3) the philtrum, 4) the nasolabial sulcus, 5) the geniolabial sulcus, 6) the commissures of the mouth, and 7) the facial profile.

Since EMG was introduced by Moyers (1949), several studies have investigated postural jaw position where masticatory muscle activity was minimal.

Shpuntoff and Shpuntoff (1955) used a method to locate the mandibular postural position, where subjects observed an oscilloscope trace of a signal from the masseter muscles in the form of EMG visual feedback. This technique was to enable subjects to maintain a position of minimal jaw muscle activity. However, there was no comparison with other methods and no quantitative details of the dimensions of the free- way space.

The so called "rest" position induced phonetically by Jarabak (1957) in both dentate and edentulous subjects was found to correspond with electrical silence in elevator and depressor muscles. However, during slow closure from wide opening, the masseter and temporal muscles were inactive until occlusal contact was made.

This suggests that elevators are electrically inactive over a range of lower face height distances rather than at a specific jaw position.

Garnick and Ramfjord (1962) used surface EMG recordings from temporal, masseter and digastric muscles and observed a resting range in the jaw muscles.

The clinically determined postural jaw position was not located within the electromyographically determined resting range of muscles in the majority of subjects. The average IOD obtained by EMG was significantly greater than that determined by phonation and swallowing. Similar results were observed by Rugh and Drago (1981), who found that minimal muscle activity did not coincide with PJP, and jaw muscle activity was not minimal or absent at postural jaw position. This data is in contrast to the findings of Shpuntoff and Shpuntoff (1955), but reflected the differing study designs.

Manns et al (1981) observed the changes in EMG activity of the masseter, anterior temporal, and posterior temporal muscles on the left side of the subjects with varying the vertical dimensions and found that on jaw opening from closure, masseter and temporalis activity first declined to minimal levels and was followed by an increase with wider opening. In both muscles, minimal activity was found to correspond to a face height which was significantly greater than the PJP.

Watkison (1987) reviewed the relationship between postural jaw position and muscle activity in jaw muscles and suggested that the clinically determined PJP did not coincide with the position of minimal activity as determined electromyographically.

Several studies that compared the mandibular "rest" positions induced by different methods have been published (Feldman et al 1978, Wessberg et al 1983, Babu et al 1987).

Feldman et al (1978) compared "rest" vertical dimension induced by electromyography with biofeedback from the skin over both anterior temporal muscles, with postural position determined by conventional methods (phonetics and swallowing), and concluded that a more expanded study is necessary to determine the validity of electromyography versus conventional methods for determining postural vertical dimension. They also questioned both methods in relation to the time of day, patient's understanding of each technique, and past dental history.

Babu et al (1987) conducted an experiment to compare the PVD determined by conventional methods (phonetics and swallowing methods) with EMG activity obtained from the masseter and anterior belly of the digastric muscles of the right side of dentulous and edentulous subjects using biofeedback. They concluded that the

PVD determined by both methods was similar in dentulous subjects. The authors found that the difference in the PVD in edentulous subjects with complete dentures was not significant, but without dentures the difference was statistically significant. Wessberg et al (1983) compared IOD induced by phonetics, transcutaneous electrical stimulation (TENS), and minimum integrated jaw muscle (both masseter muscles) EMG activity. The data obtained from four adult women with normal dentofacial morphology demonstrated that the mean IOD at the position induced by phonetics was significantly less than at the position induced by the other two methods. The mean IODs by TENS and jaw muscle activity were twice the mean IOD by phonetics. The authors referred the jaw position induced by phonetics as the clinical rest position of the mandible (CRPM) and the jaw position induced by TENS and EMG recording as the physiologic rest position of the mandible (PRPM). Their study suggested that more than one "rest" position of the mandible existed in the subjects, although their experiment only performed on a limited number of subjects, and the importance of utilizing TENS and EMG recording in relation to establishing PJP needed to be re-evaluated with sufficient number of subjects in the future study.

EMG studies of the jaw muscles related to postural position have been focused on masseter and temporalis muscles. However, the mentalis muscle, located below the lower lip, is another contributing factor in determining postural jaw position due to its functional influence on the position of the lower lip.

The importance of lip support to determine the postural jaw position was raised by Arstad (1965). He emphasized the influence of the lips on the mandibular "rest" position in edentulous patients and advocated the importance of building the occlusal rims to support the lips fully before establishing the PVD. On the contrary, the most recent study done by Ekfeldt and Karlsson (1992) to assess the possible influence of differences in lip support on determining a postural jaw position in edentulous subjects concluded that no significant differences were found in postural jaw positions between with and without labial support of the occlusal rim. They pointed out one possible reason why their conclusion was conflicting Arstad' study (1965) was that there were numerous factors influencing recorded PVD at a given time, although both studies were based on the edentulous subjects.

The mentalis muscle originates from the symphysis of the anterior mandible, at the level of and below the incisor tooth roots (Figures 1 – 3: taken from http://face-and-emotion.com/dataface/anatomy). The area of origin appears to be circular and about the width of the incisor teeth. The fibers are relatively compact at the origin and pass outward and downwards into the skin over the front of the chin. (Gray 1918).

The function of the muscle is to compress the skin of the chin against the anterior mandible and also elevate the skin, which affects the position of the lower lip as well as the position of the incisor teeth (Ballard 1953).

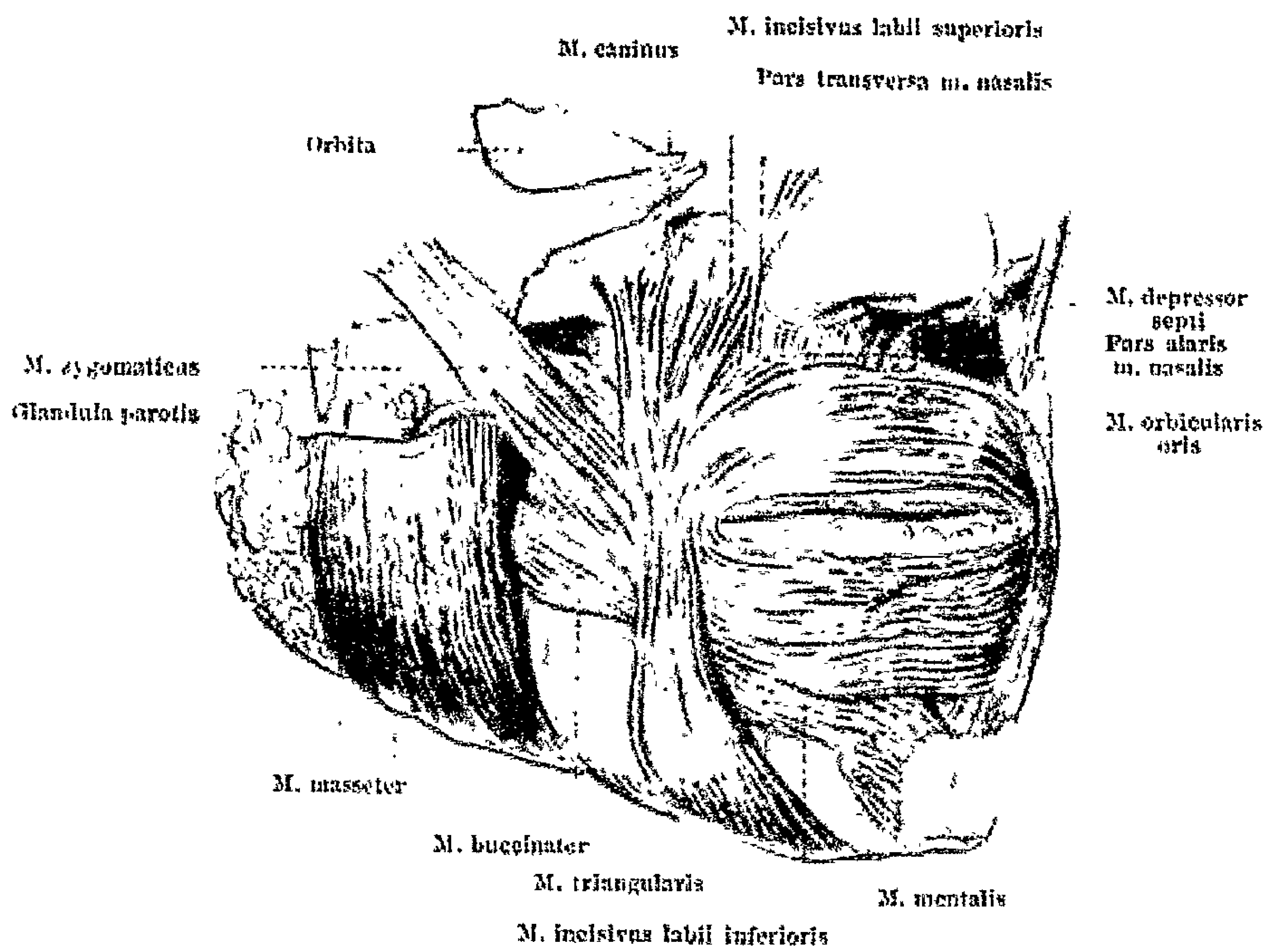

Figure 1 Anatomical view of mentalis muscles-I. (http:// face-and –emotion.com)

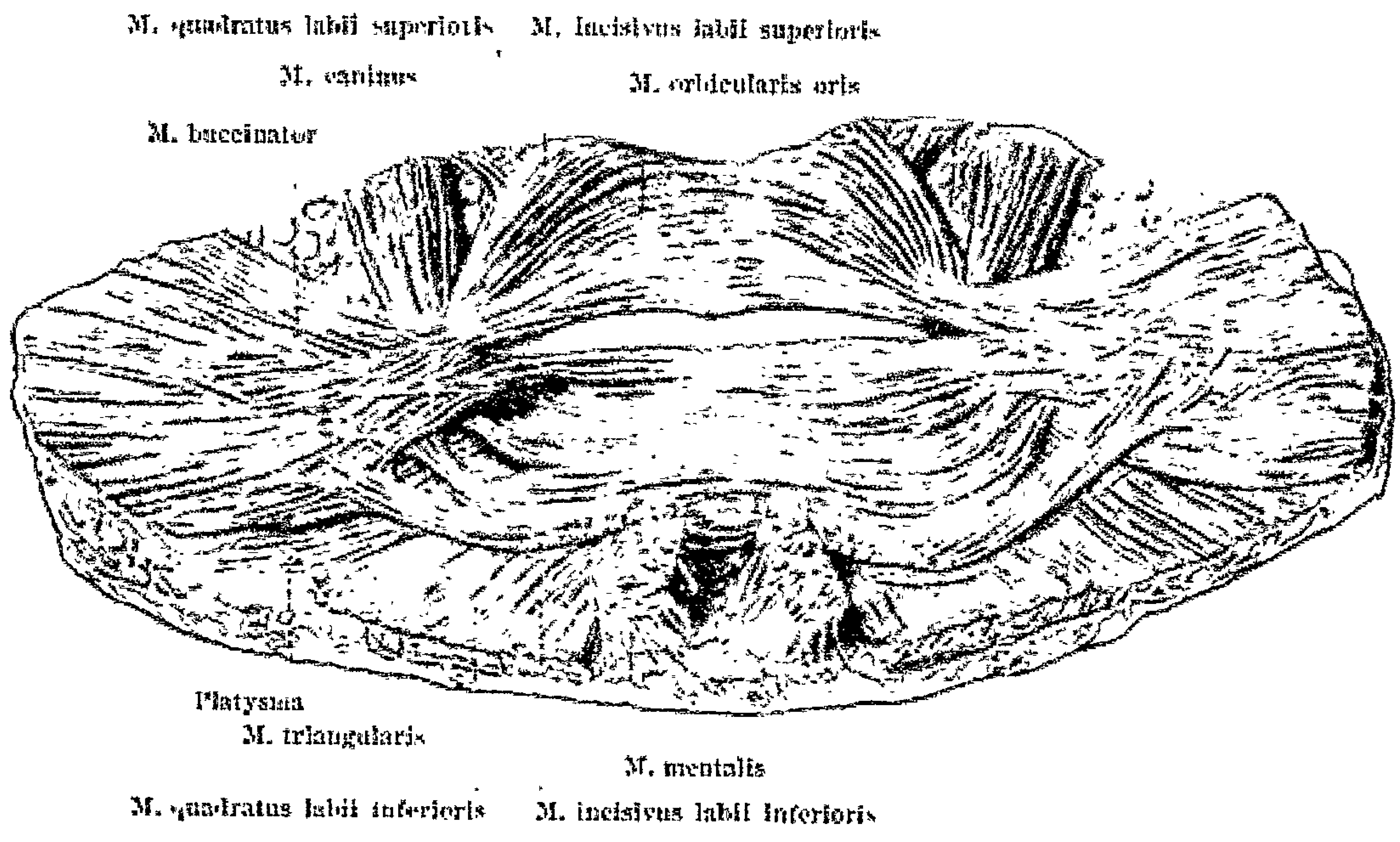

Figure 2 Anatomical view of mentalis muscles-II. (http:// face-and –emotion.com)

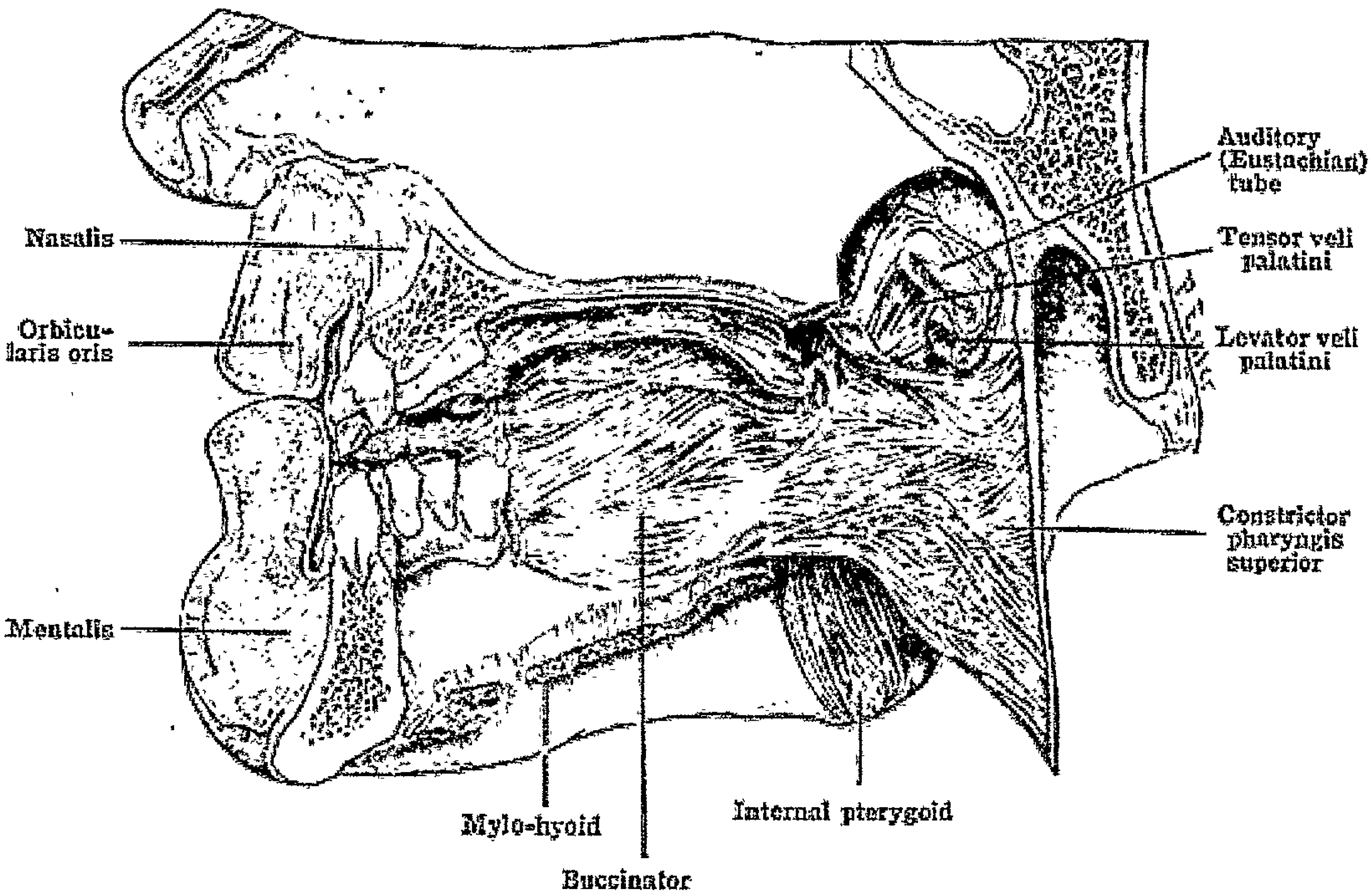

Figure 3 Anatomical view of mentalis muscles-III. (http:// face-and –emotion.com)

Visual observation of changes in tone of the skin of the chin has been used as a useful clinical sign to assess whether the lips are pulled together abnormally from a postural position at an incorrect OVD (occlusal vertical dimension). This is related to the function of mentalis muscle.

If the OVD is decreased, the closing muscles will not be lengthened completely during opening or at postural position. This causes wrinkles around lips and accentuates the geniolabial sulcus. On the other hand, if the OVD is increased excessively, the muscles of closure stretch beyond their physiologic length and will cause a strained-looking face, and this results in changes in the tone of the mentalis muscle.

There are limited studies available, which utilize subjective assessments using clinical photographs to evaluate the effects of increasing OVD or PVD on the facial features.

Mohindra and Bulman (2002) conducted questionnaires to assess the effect of increasing OVD on facial aesthetics by asking the patients' opinion the effects of the treatments on their facial features.

Most of the patients (79.7%) reported that their appearances had been improved after the treatment. To obtain an objective view, clinical photographs before and after treatments were presented to 5 observers, and they concluded that 81.2 % of the patients showed improved facial aesthetics.

However, Gross et al (2002) evaluated the effect of increasing OVD and PVD on the face height in completely dentate young adults. They increased OVD and PVD in interincisal increments of 2, 4, 6, and 8mm from a maximal intercuspal position (MIP). Subjective assessments of the changes in face height using the photographs were made by 10 observers. The results showed that detecting changes in face height by observers was not viable in the ranges of 2, 4, and 6mm for both MIP and “rest” position and there was no interaction between the accuracy of observer evaluation and the changes in OVD.

The above studies evaluated the effects on facial features with varying vertical dimensions, they did not focus on the changes of a certain jaw muscle but on the effects on the lower face height. Not a single study was found to advocate the effects on the mentalis muscle in relation to various vertical dimensions visually or electromyographically.

This study was undertaken to investigate the relationship between EMG activities and visual changes of the mentalis muscles with a range of vertical dimensions from postural jaw position and to attest the value of visually determining differences in the mentalis muscle in establishing a correct OVD.

AIMS

The aims of this study are to investigate the activity of the mentalis muscle with increasing facial vertical dimensions from the PJP as the reference point, determined clinically in dentate subjects, and to compare these changes by visual observation of the tension of the mentalis muscle. Observations are to be made by different clinicians from clinical photographs taken at the same time as the EMG recordings.

MATERIALS AND METHODS

The study was carried out with twenty subjects (7men and 13women), who volunteered from among staff members of the Westmead Centre for Oral Health. The age range was 23 to 67years, and all subjects did not report on any clinical signs or symptoms of temporomandibular disorders.

Each subject had a sufficient number of teeth to allow maxillary and mandibular casts to be hand articulated and to be horizontally and vertically stable without an interocclusal recording.

The experimental procedures were explained to each subject, who singed a written Consent Form agreeing to participate in the study.

Preparatory phase

During preparatory phase, the following procedures were performed for each subject.

1. Maxillary and mandibular impressions of an each subject were taken with irreversible hydrocolloid (Alginate) to fabricate casts, and a facebow transfer record was taken to articulate the maxillary casts on a semi-adjustable articulator (Denar Mark II, Denar Corp, USA). The articulator was set with 25° condylar guidance and 7.5 ° progressive side-shift.
2. The postural jaw position was assessed by asking a subject to relax, lick their lips, and say 'M, M, M'. As a result the subject put the lips but not the teeth together lightly, and the chin tension of the mentalis muscle was observed at the same session.

3. A Willis gauge (S.S White Dental Products, Kingston-upon-Thames, England) was used to measure the distance between the OVD and the PVD.
4. The maxillary cast was articulated with the facebow transfer record and horizontal and vertical stability of the hand – articulated casts was assessed and secured with sticky wax.
5. The mandibular cast was duplicated before articulating and used to fabricate a vacuum formed wafer for a mandibular splint.

   The wafer (Figure 4) was constructed with a preformed 0.8mm thermoforming disc (Erkodur®, Erkodent® Erich Kopp GmbH, Pfalzgrafenweiler, Germany) using a vacuum forming machine (Erkopress®, ES2004, Germany) to mould the disc to the mandibular arch of teeth. The wafer was placed in each subject's mouth, and its fit was assessed and checked, and adjusted if necessary.
6. The wafer was returned to the articulated mandibular cast and the articulator incisal pin was open to the same difference between OVD and PVD measured with a Willis gauge to build –up a mandibular splint with auto-polymerising acrylic (Dura-Lay, Dental Mfg, Corp, Illinois, USA). Bilateral even contacts on the fabricated splint were achieved. When the modified splint was inserted in the mouth, this jaw position was considered as a postural jaw position with a splint. The IOD or free-way space was ranged from 1 to 4mm amongst the subjects.

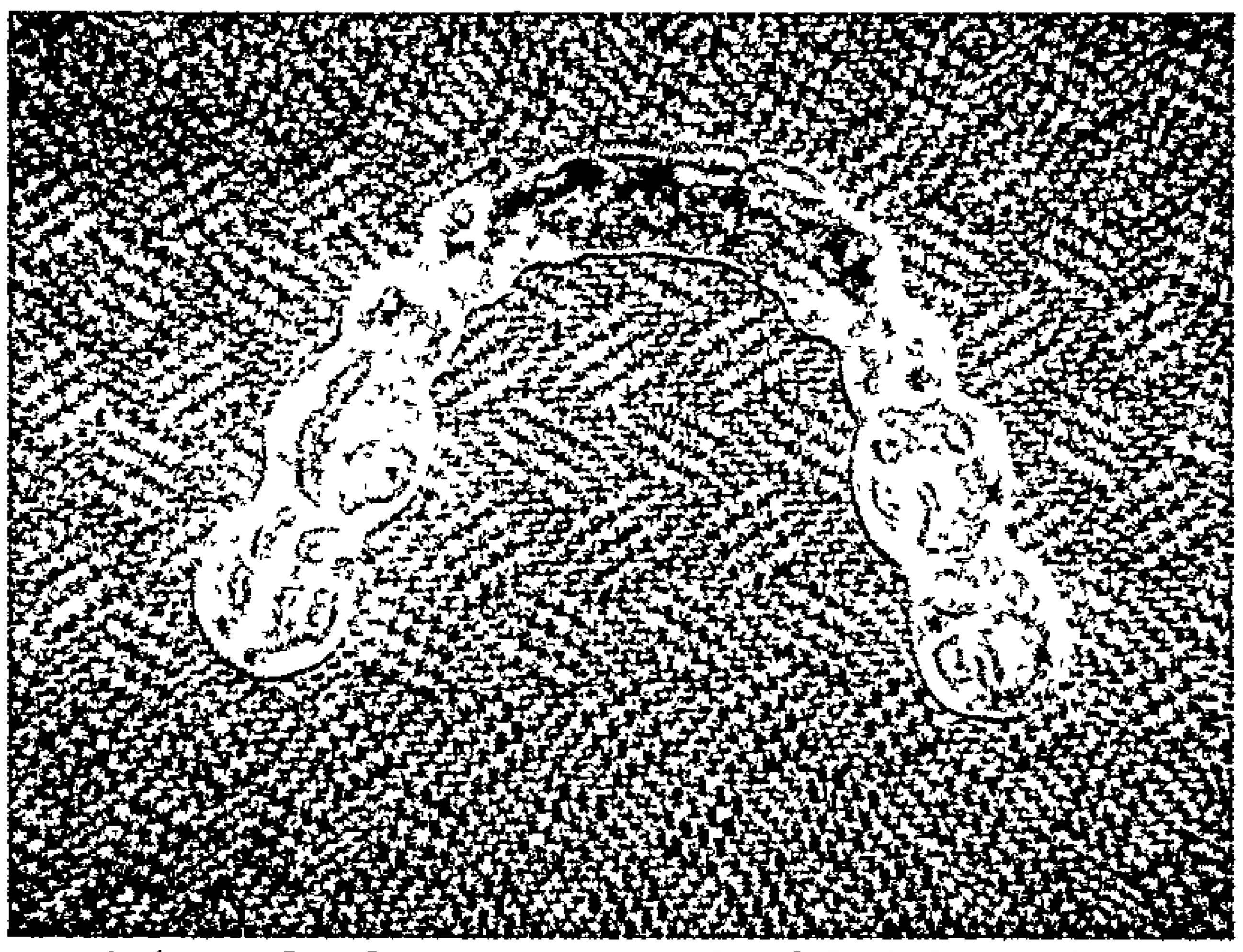

Figure 4 A wafer is constructed with 0.8mm Erkodur®

EMG recordings

The subject was seated upright in a recording chair and underwent the following procedures.

1. Topical anaesthesia (Emla®, Astra Zeneca, Australia) was applied on the skin overlying mentalis for 30-45 minutes before placing the hook electrodes. This overcame discomfort for subjects with skin penetration for electrode placements.
2. Prior to EMG recordings, the skin around orbicularis oris and mentalis of each subject was wiped with an alcohol swab to remove skin oils, dirt or any remnants of cosmetics.
3. EMG recordings were acquired with hook electrodes (Figure.4) over the mentalis and placed 1-2mms apart for bipolar recordings. This ensured that the electrodes did not contact during minor muscle movements and thereby interfere with the EMG recordings.
4. Two surface tin-cup electrodes (Figure.5) were also placed on the corners of the mouth to record the EMG activity from the orbicularis oris muscle. This

was necessary to eliminate any potential of movement from smiling or other facial expressions affecting the EMG recorded from the mentalis muscle activity with the varying postural positions. Electrodes were secured on the skin using adhesive tape (Johnson and Johnson, USA) and electrode gel (Signa gel®, USA) was applied on the contact surfaces of surface disc electrodes to enhance skin conductance for EMG recordings.

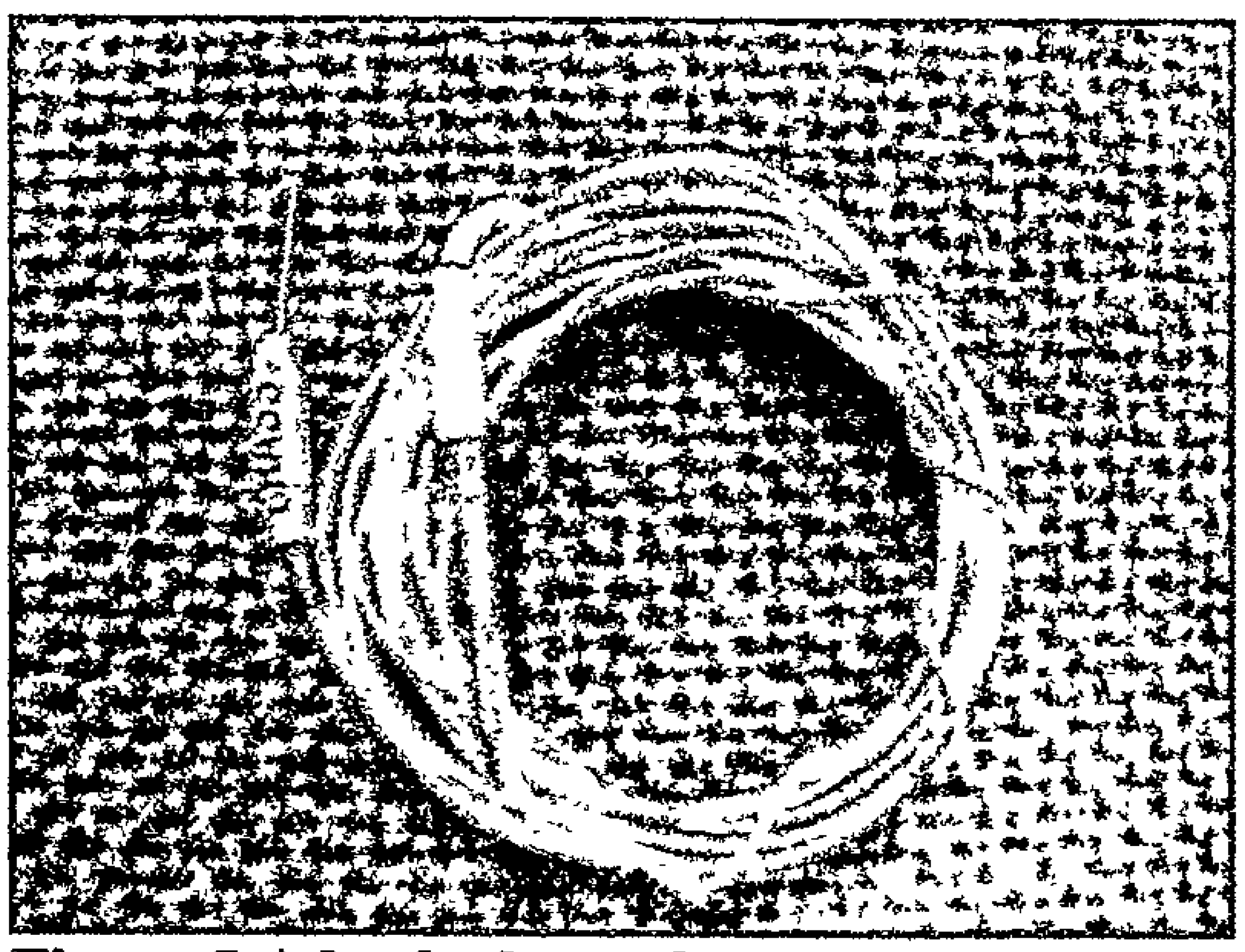

Figure 5 A hook electrode

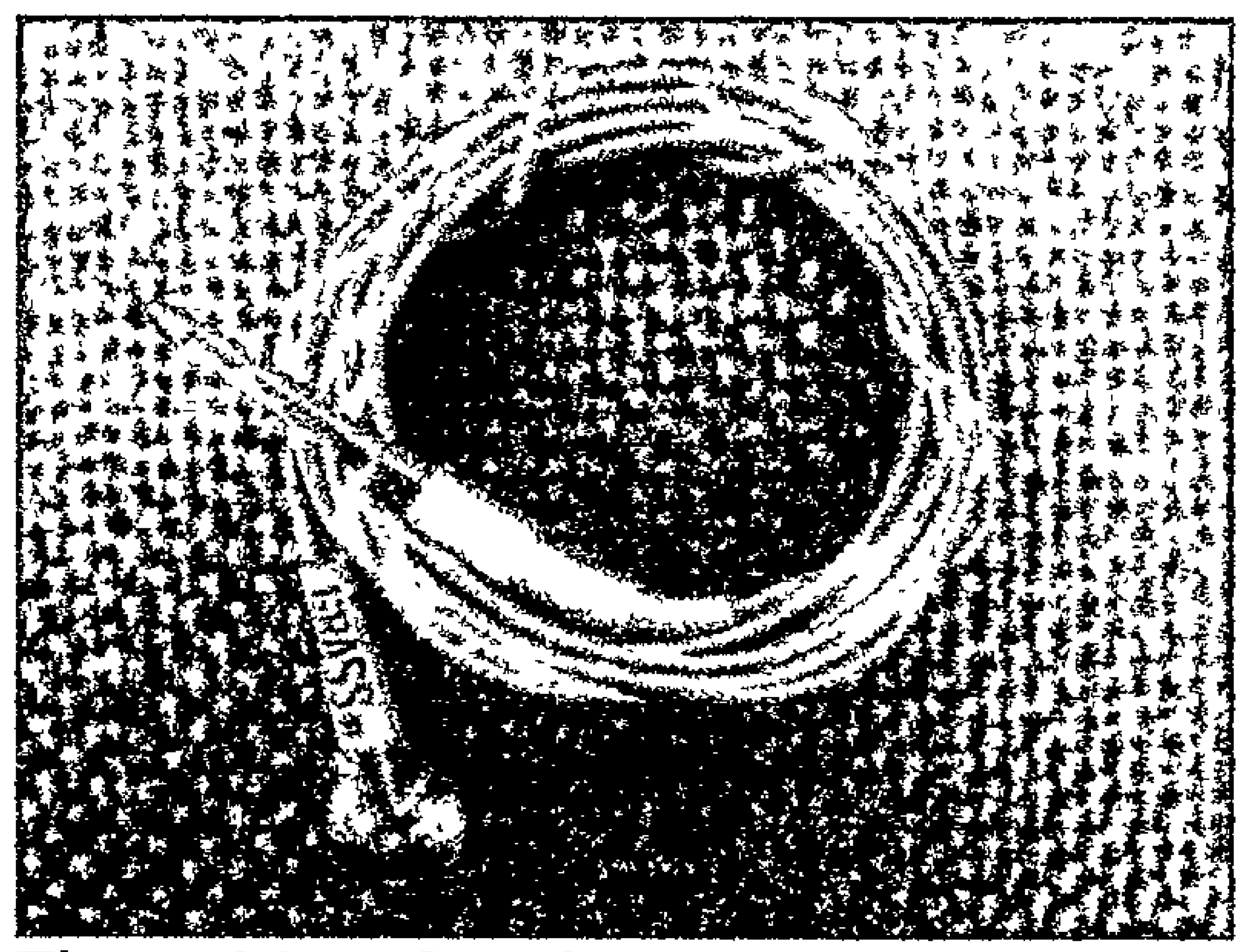

Figure 6 A surface tin-cup electrode

5. A ground electrode was placed on the subject's right wrist.
6. EMG signals were transferred to an isolated bioelectronic amplifier (SA Instrumentation Co, San Diego, CA, USA) and to a digitizer (CED2501, Cambridge Engonemy Design, Cambridge, UK) to convert analogue to digital signals. The digitized EMG data was acquired and analysed by the Spike-3 programme.

Each recording was called a trial and repetitions of trials called a set

Recording protocol required eight sets of trials corresponding to jaw position as accompanied by clinical photographs of the subject for each trial

- The protocol consisted of :

a) Pre-experimental stage consisting of 3 jaw positions; an intercuspal position without the splint, postural position without the splint, and postural position with the splint,

b) Actual experimental stage consisting of 3 jaw positions; postural position increased by 2mm, postural position increased by 4mm and postural position increased by 6mm. These were performed in random order to eliminate order effects and

c) Post-experimental stage consisting of 2 jaw positions; intercuspal position without the splint and postural position without the splint to evaluate any remaining effects of the recordings.

- Pre-recording and post-recording stages were repeated three times, a total of 15 trials, and the experimental recordings were repeated five times, a total of 15 trials. Each subject was asked to lightly contact the modified splint and to bring the lips together before a trial was started.
- At each trial, EMG activity was recorded for 20 seconds.
- A digital camera (Nikon, Coolpix 4300, Nikon Corp, Japan) was used to obtain clinical photographs during the recordings. Before its use the camera was calibrated to standardise the distance from the lens to the chin as well as the settings for each subject. The distance from the lens to the chin was 66.5mm and the settings were as follows. : The focal depth was 4.9 and shutter speed was 1/60. Clinical photographs were taken before and after an each repeated trial.
- Each subject was asked to complete a visual analogue scale (VAS) to measure any pain, stress, and anxiety at the end of each trial. This

procedure was carried out to record individual levels of pain, stress, and anxiety of each subject during the experiments, as these are known to be factors which may affect the registering of maxillomandibular relationships (Obrez and Turp 1998).

Rating of Clinical photographs

For each subject, an average of 60 clinical photographs was taken. One photograph was selected to represent the different vertical dimensions at which EMG recordings were made, and comprised of five photographs of postural position.: 1) without the splint, 2) postural position with the splint, 3)postural position + 2mm, 4) postural position +4mm, and 5) postural position + 6mm for each subject. A set of photographs for one subject that was presented to observers is shown in Figure.7. (A-E)

Three independent clinicians with different levels of clinical experience volunteered to assess the photographic records for this study. One rater is dental officer of 3 years clinical experience, another is a prosthodontist of 15years clinical experience, and the other is a senior consultant prosthodontist.

Five clinical photographs (Appendix1) for each subject were presented in power point format to each of the three clinicians, with instructions (Appendix 2) to rate the images as indicated. The clinicians were in a quiet room alone while rating and were blinded to the clinical specifics of each recording.

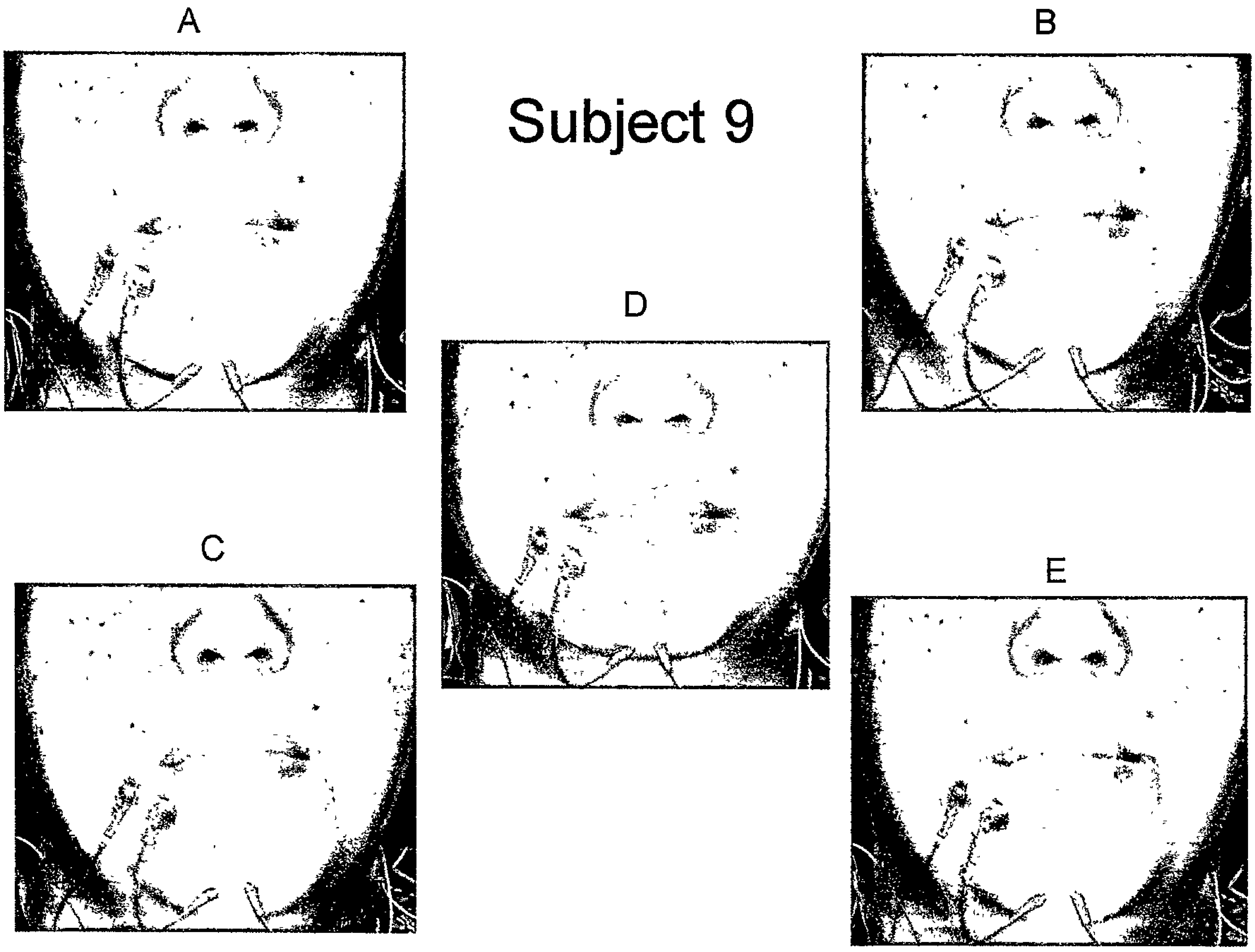

Figure 7 An example set of photographs for one subject presented to observers

Data analysis

EMG recordings

Multiple trials of 20 seconds duration were performed for each subject at the different vertical dimensions and in each trial EMG recordings were obtained. The raw EMG activity recorded from mentalis and orbicular oris muscles was transferred to an isolated bioelectronic amplifier (SA Instrumentation Co, San Diego. CA. USA) and to a digitizer (CED2501, Cambridge Engonemy Design, Cambridge) to convert the analogue to digital signals.

To quantify the EMG data for the mentalis muscles, Root mean square (RMS) values were calculated for each subject at different vertical dimensions on each trial from 2 to 18 seconds, and the data was analysed using the Spike-3 programme. Any activity corresponding to in the orbicularis oris was eliminated form the analysis

As a result, paired T- test with Bonferroni correction (corrected for multiple comparisons) was used to test the statistical significance of the EMG activity between the different vertical dimensions. A p value of < 0.05 was considered to be statistically significant.

Clinical photographic analysis

The five selected clinical photographs for each subject with different vertical dimensions were presented to the observers to rate the photographs as indicated. Their ratings were evaluated for each subject and for each different vertical dimension to assess the ability of the observers to rate the photographs correctly. In a study of this type where assessments are made by different clinicians, it is important to establish how much agreement there is between them. Cronbach's alpha coefficient is a useful statistic for investigating the inter-rater reliability, which ranges from 0 to 1. To formulate Cronbach's alpha using SPSS (Statistical Package for the Social Sciences) version 12.0.1, numbers of items (N) and average inter-item correlation among the items (r bar) are required (formula shown below).

$$\alpha = \frac{N \cdot \bar{r}}{1 + (N-1) \cdot \bar{r}}$$

The widely- accepted cut-off point for Cronbach's alpha is 0.7 or higher for a set of items to be considered a scale (Cronbach 1951).

RESULTS

EMG recordings

This part of the study was to observe differences in EMG activity in mentalis muscle at different vertical dimensions, and to determine whether the differences were statistically significant.

For each subject, EMG recordings for multiple trials of 20 seconds were obtained at each vertical dimension. With each subsequent increase in vertical dimension, 3 sets of trials in postural position with and without a splint respectively, and 5 sets of trials for postural position +2mm, +4mm, and +6mm were performed and EMG recordings taken.

During experiments, the subjects were asked to complete a VAS with regard to any pain, stress, or anxiety at the end of each trial. VAS scores reported by subjects were considered negligible to influence EMG recordings of the mentalis muscle, if below 10 out of 100. All 20 subjects reported less than 24 (ranging from 0-24) out of 100 in pain intensity, and Figure 8 illustrates the means of pain intensity for each subject. Most of subjects (80%) reported VAS scores less than 10 out of 100.

Concerning stress levels, the ranges on the VAS were from 0 to 31 out of 100scales. Figure 9 illustrates the means of stress intensity for each subject. Most of subjects (70%) reported VAS scores less than 10 out of 100.

The anxiety scores were less than 27 out of 100 scales except for one subject, who showed 75 out of 100 at the beginning of the trials, although the level of anxiety for this subject decreased with progress of the recordings. The means of anxiety for each subject showed in Figure 10. More than half subjects (65%) reported VAS scores less than 10 out of 100.

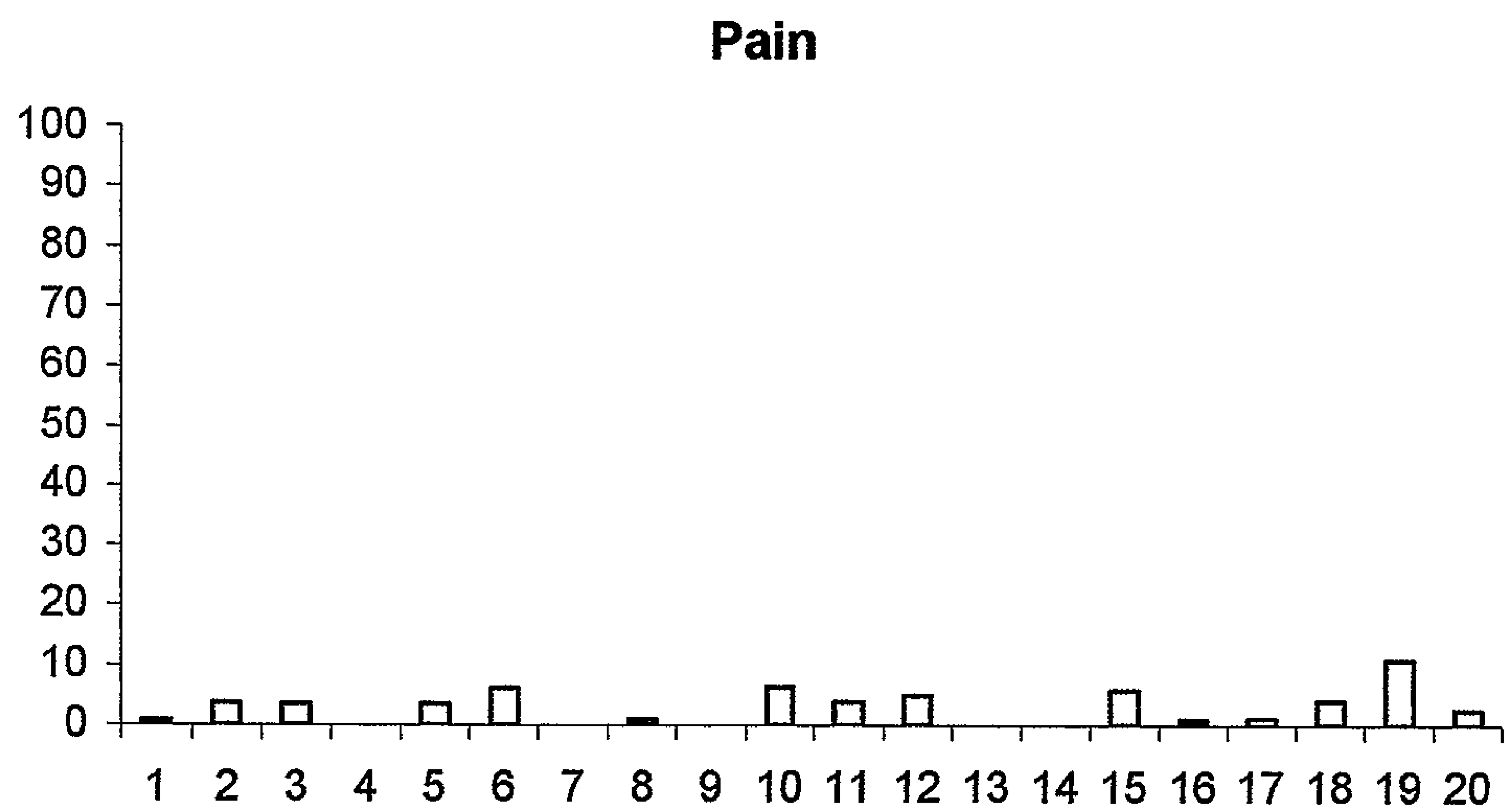

Figure 8 The means of pain levels of individual subjects during the recordings. X-axis; the subjects, No.1-20, Y-axis; VAS from 0-100

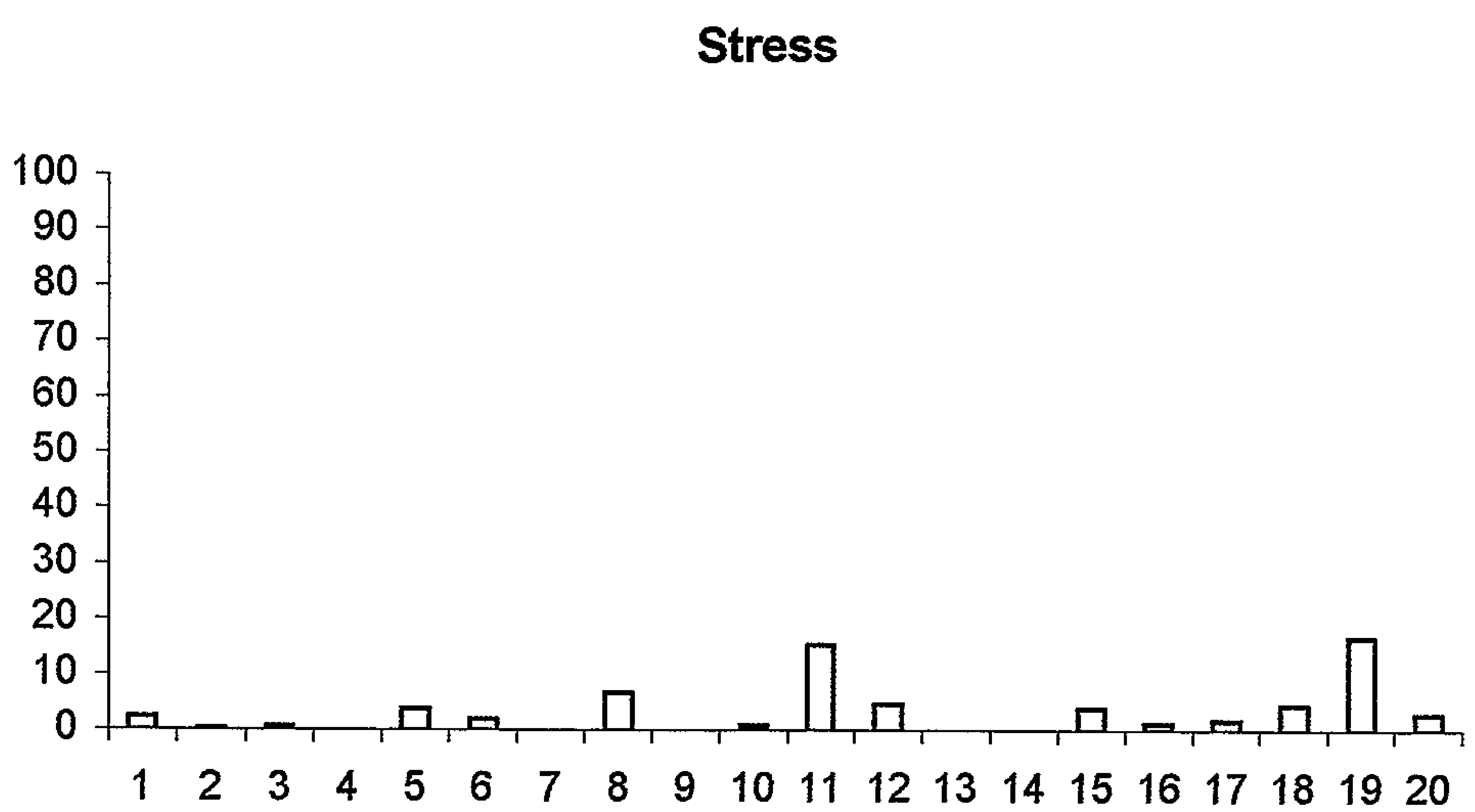

Figure 9 The means of stress levels of individual subjects during the recordings. X-axis; the subjects, No.1-20, Y-axis; VAS from 0-100.

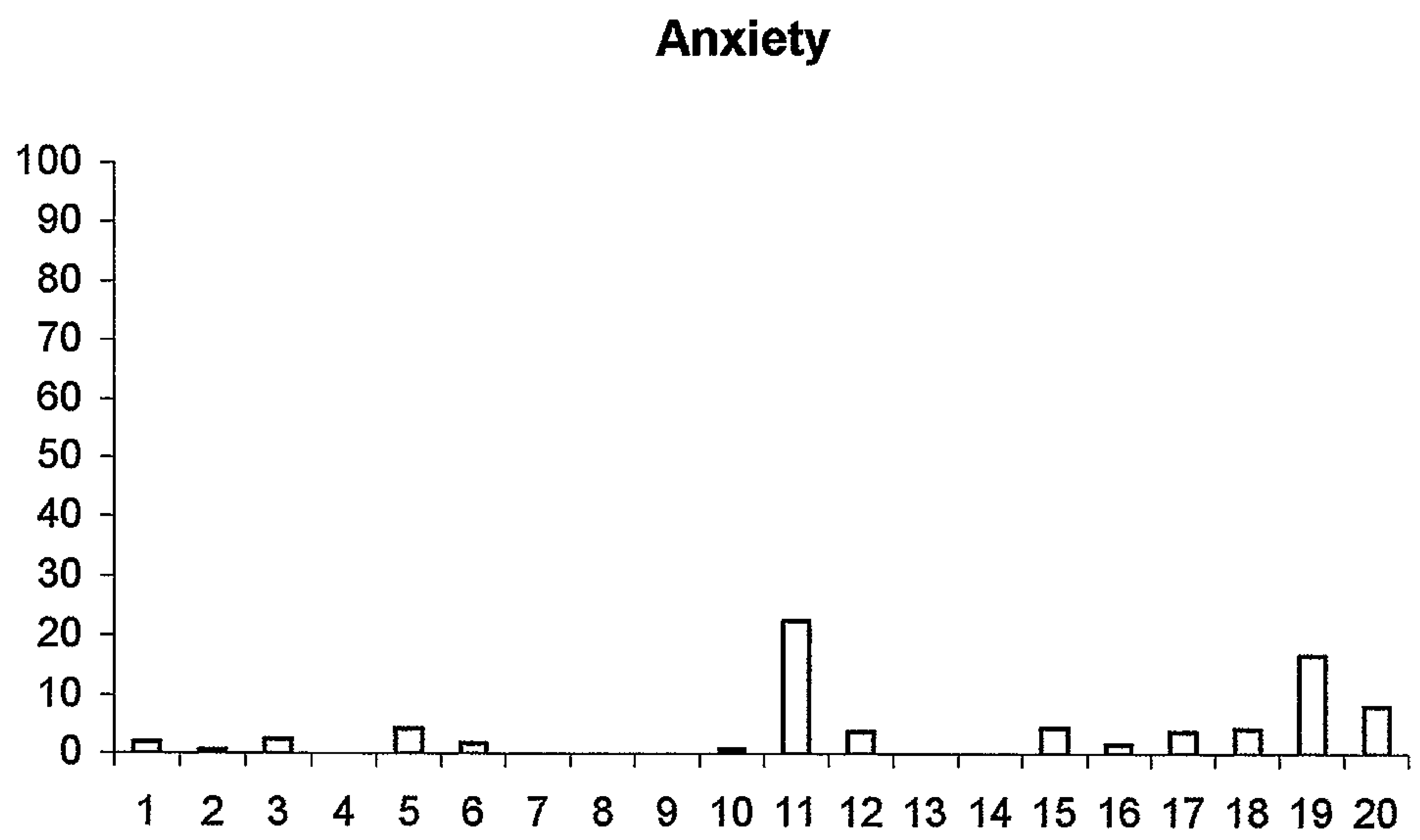

Figure 10 The means of anxiety levels of individual subjects during recordings. X-axis; the subjects, No.1-20, Y-axis; VAS from 0-100.

EMG analysis

In order to quantify the results of the EMG recordings, the RMS from 2 to 18 seconds was calculated using the Spike - 3 programmes. Figure.11 illustrates examples of EMG recordings of a subject at different vertical dimensions.

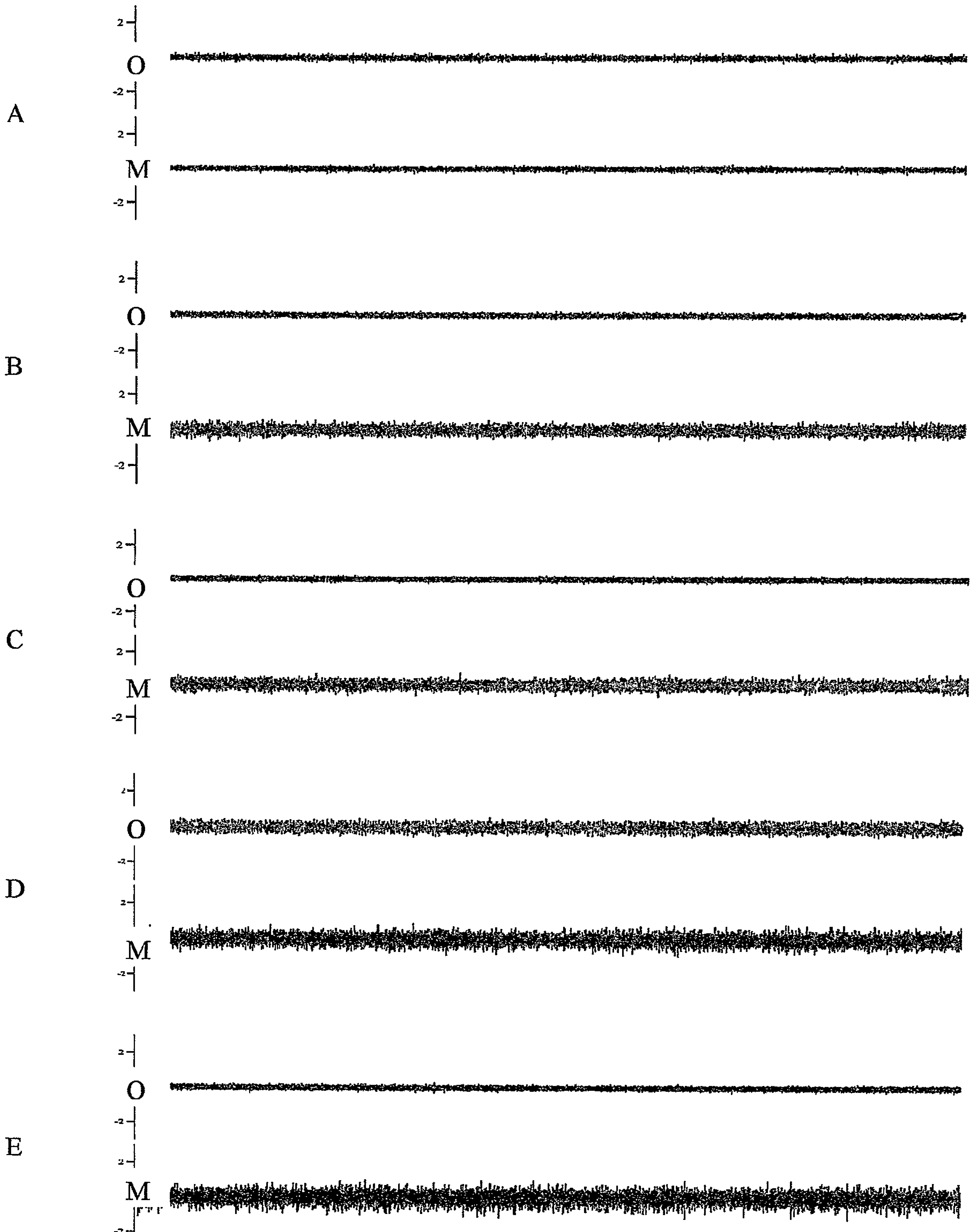

Figure 11 Examples of EMG recordings of a subject at different vertical dimensions

O: Orbicularis oris, M: mentalis, A: PP without a splint, B: PP with a splint,

C: PP+ 2mm, D: PP+4mm, E: PP+6mm.

Thus, each subject had a) 3 values for the area under the EMG curve in postural position with and without a splint respectively, and b) a total of 5 values for each of the three jaw positions with change in vertical dimension. The RMS values with the standard deviations were calculated for each subject at different vertical dimensions. Table 1 shows that the means of the RMS values of the mentalis muscle increased progressively at different vertical dimensions.

	Means of RMS	N	Std. Deviation	Std. Error Mean
Postural position (PP) without a splint	0.0767	60	0.0641	0.0083
Postural position (PP) with a splint	0.1159	60	0.0974	0.0126
Postural position (PP) +2mm	0.1326	100	0.1032	0.0103
Postural position (PP) +4mm	0.1802	100	0.1346	0.0135
Postural position (PP) +6mm	0.2359	100	0.1780	0.0178

Table 1 The mean value of RMS of mentalis muscles at different vertical dimensions. (Expressed to four significant figures)

The mentalis muscle activities between the postural position with a splint and without a splint were paired to test the influence of a splint on EMG recordings. The paired samples test using SPSS was used with 95 % confidence interval of the difference. The results presented in Table 2.

	Paired Differences					P value
	Mean	Std. Deviation	Std. Error Mean	95 % confidence interval of the difference		
				lower	upper	
Postural position(PP) with / without a splint	-0.0393	0.0530	0.0068	-0.05300	-0.0256	0.000

Table 2 Paired samples test with 95 % confidence interval of the difference (d f =59, expressed to four significant figures)

Statistically significant differences in the mentalis muscle activity are shown between the RP with a splint and without a splint.

Table 3 shows the results of the paired samples test using SPSS with Bonferroni correction that was applied to test the statistical significance of the EMG activity between the different vertical dimensions. These results show that there are significant differences in EMG activities of the mentalis muscle with varying vertical dimensions.

Pairs	Paired differences					P value
	Mean	Std. Deviation	Std. Error Mean	95%Confidence Interval of the Difference		
				Lower	Upper	
1. PP with a splint/ RP+ 2mm	-0.0150	0.0444	0.0057	-0.0265	-0.0036	0.011
2. PP with a splint/ RP+ 4mm	-0.0623	0.0804	0.0104	-0.0831	-0.0415	0.000
3. PP with a splint/ RP+ 6mm	-0.1200	0.1283	0.0166	-0.1531	-0.0868	0.000
4. PP + 4mm/ 2mm	0.0476	0.0657	0.0066	0.0345	0.0606	0.000
5. PP + 6mm/ 4mm	0.0557	0.0781	0.0078	0.0402	0.0712	0.000
6. PP+ 6mm/ 2mm	0.1033	0.1063	0.0106	0.0822	0.1243	0.000

Table 3 . Paired samples test with 95% confidence interval of the difference (pair 1, 2, and 3: d f =59, pair 4, 5, and 6: d f= 99, expressed to four significant figures)

Clinical photographic analysis

This part of the study was to determine whether a clinically observable change in chin contour at different vertical dimensions is detectable by clinicians with various levels of clinical experience, and to assess agreement amongst observers regardless of the accuracy of these ratings.

Assessments of each subject (No.1 –No.20) performed by the 3 clinicians (A, B, and C) are illustrated (Figure.12). The percentages of correct assessments were 49%, 49%, and 37% respectively.

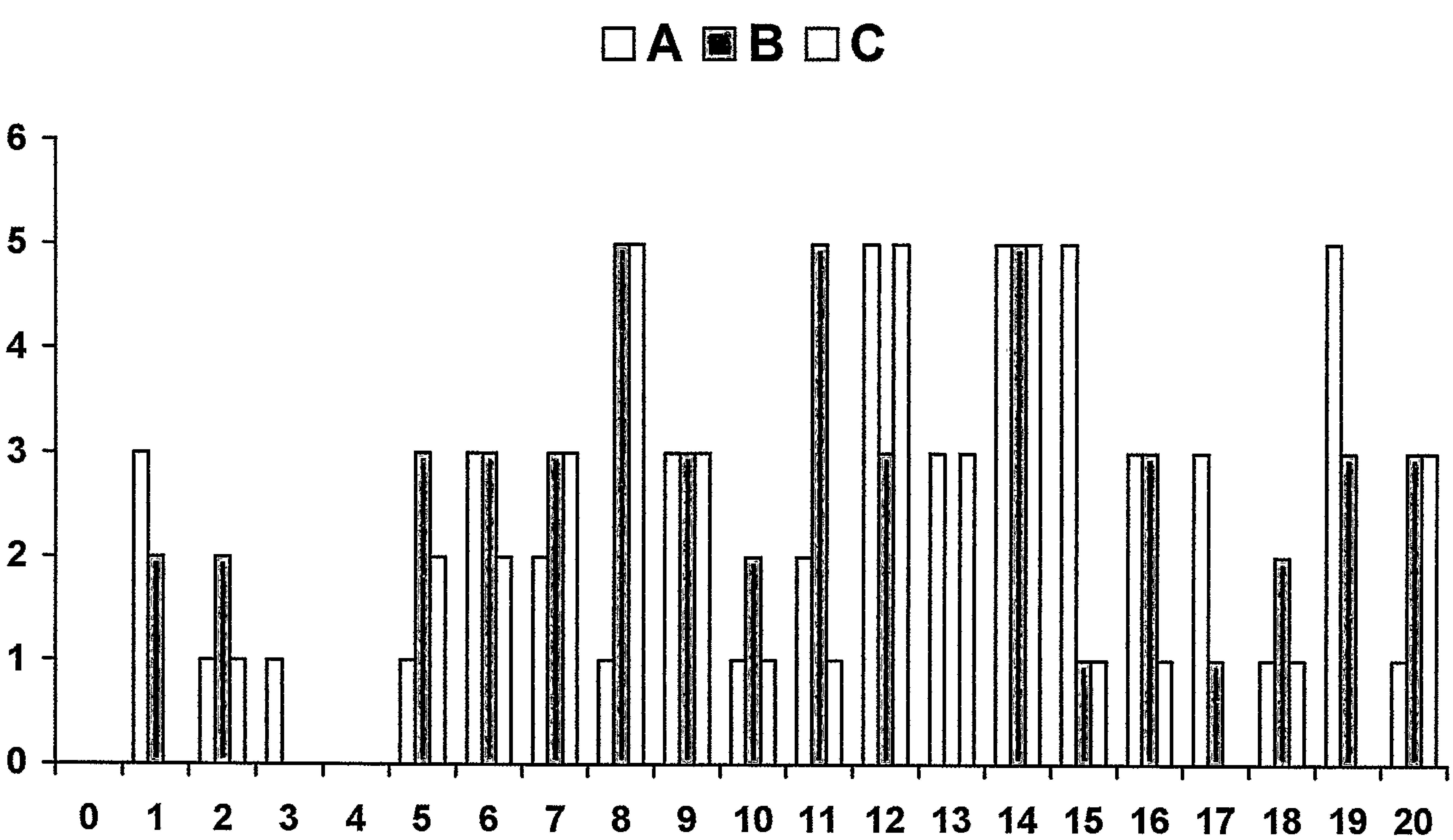

Figure 12 Assessments for each subject performed by 3 raters (A, B, and C): X- axis presents subjects from No. 1 to No. 20; Y-axis represents the number of correct assessments (0-5 for each subject.

For an individual observer, the frequency of correct assessments of clinical photographs at different vertical dimensions is analysed and is presented in Figures.13-17. Overall, clinicians A and B demonstrated similar rating outcomes compared to clinician C.

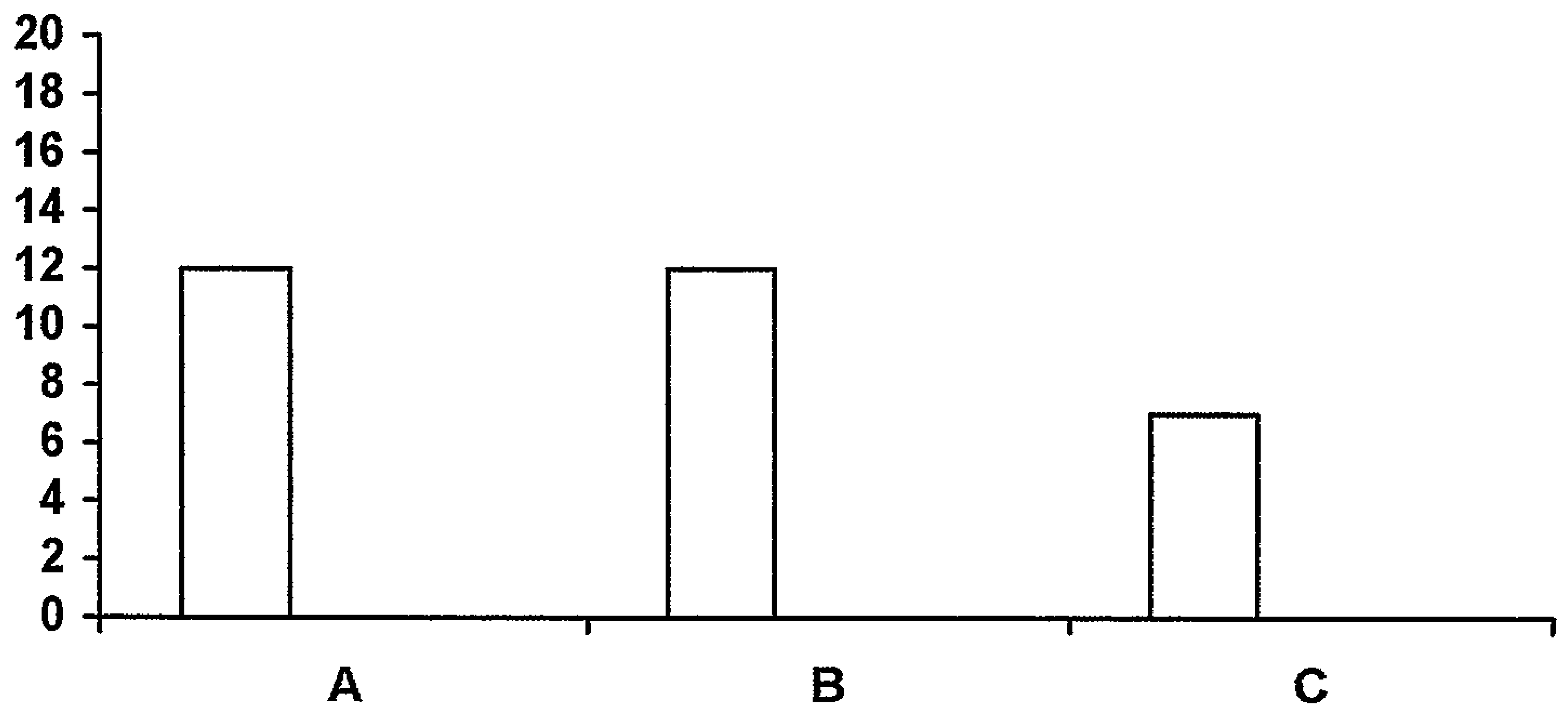

Figure 13 Numbers of correct assessment out of 20 subjects performed by 3raters (A, B, and C) at postural position without a splint: A (12/20), B (12/20), C (7/20).

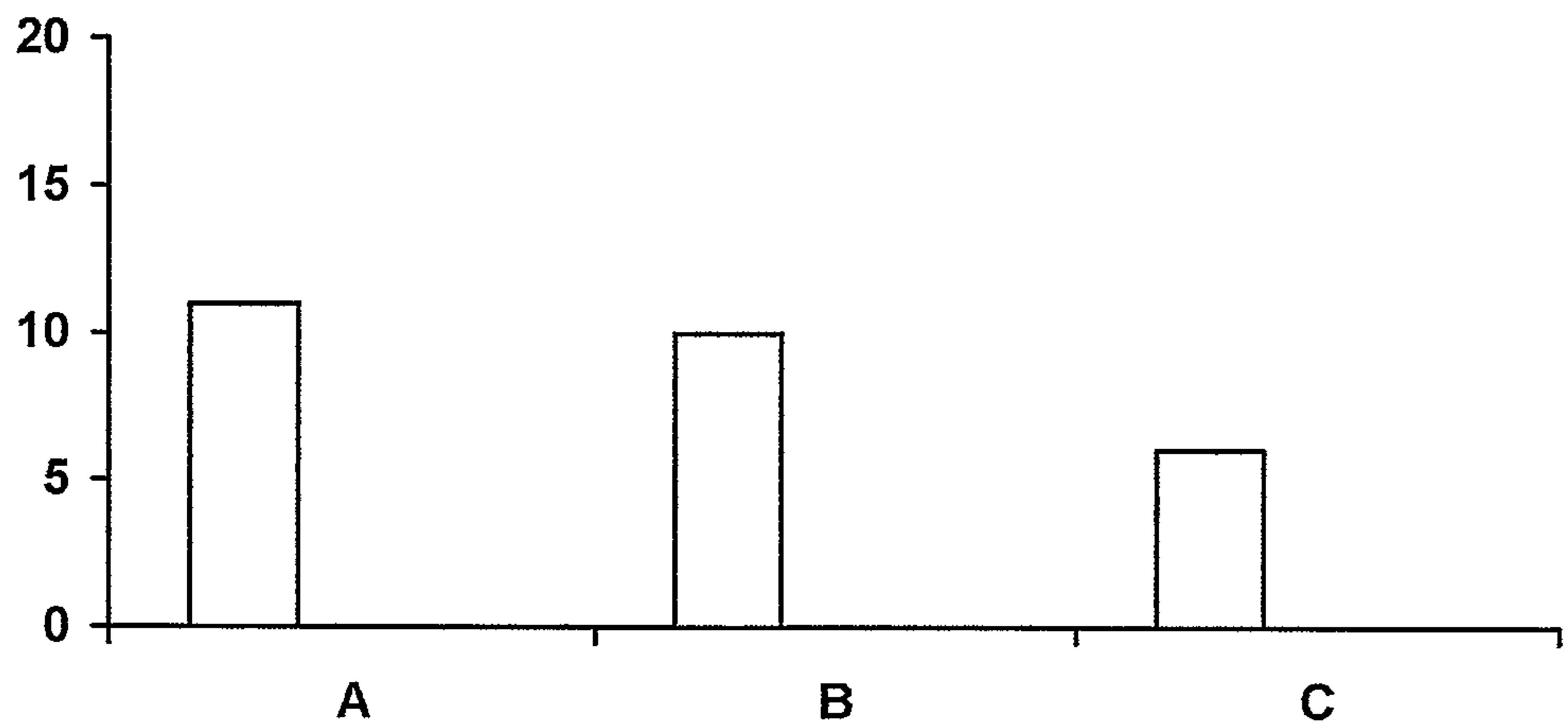

Figure 14 Numbers of correct assessment out of 20 subjects performed by 3 raters at postural position with a splint: A (11/20), B (10/20), C (6/20).

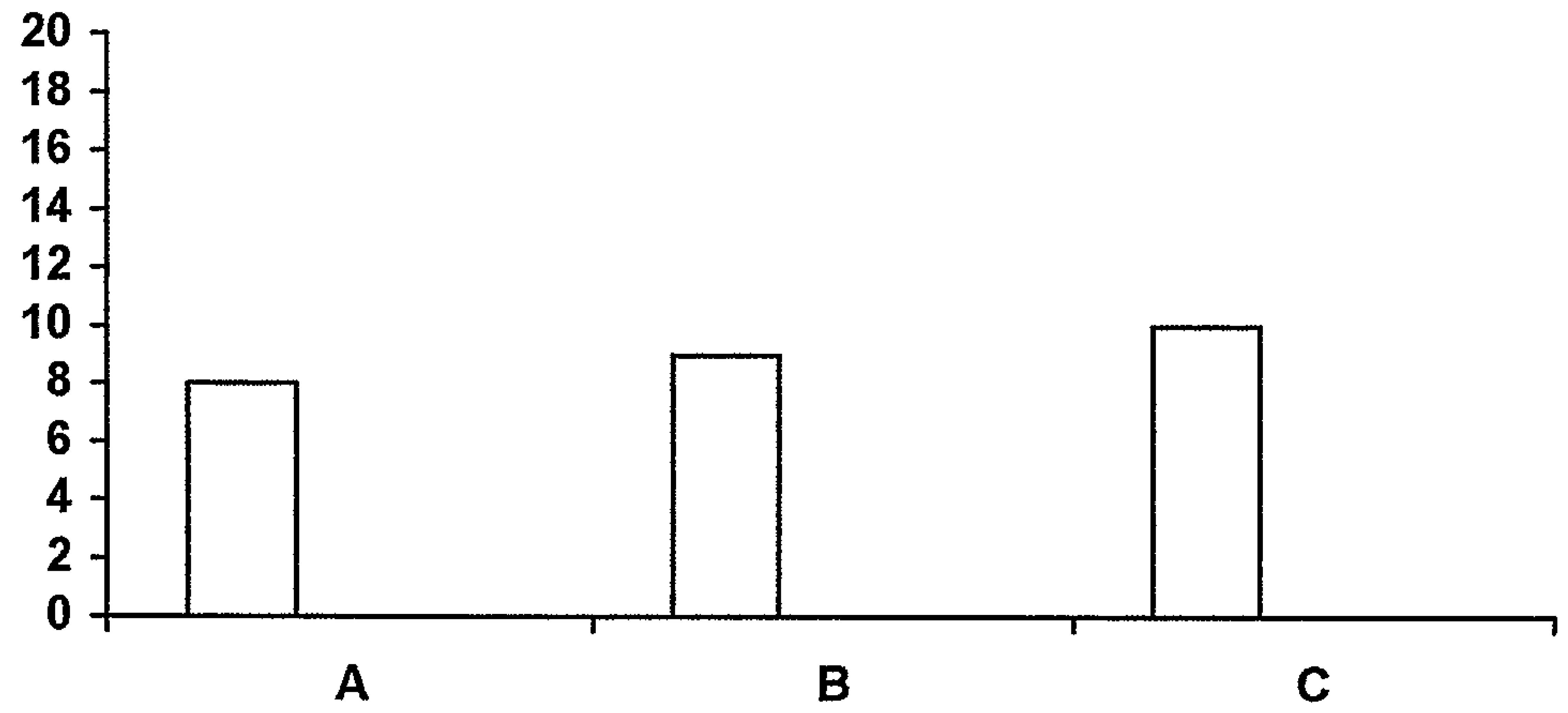

Figure 15 Numbers of correct assessment out of 20 subjects performed by 3 raters at postural position +2mm: A (8/20), B (9/20), C (10/20).

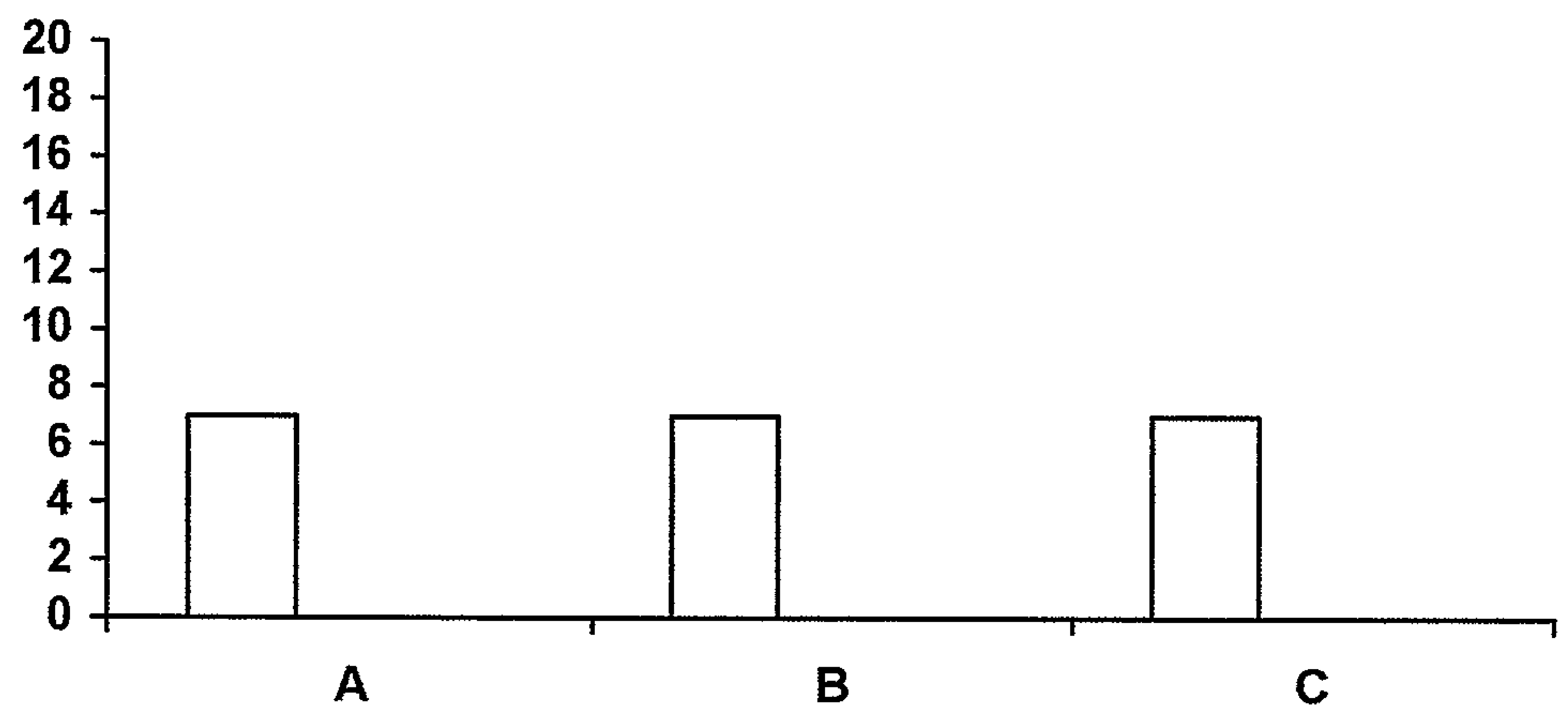

Figure 16 Numbers of correct assessment out of 20 subjects performed by 3 raters at postural position +4mm: A (7/20), B (7/20), C (7/20).

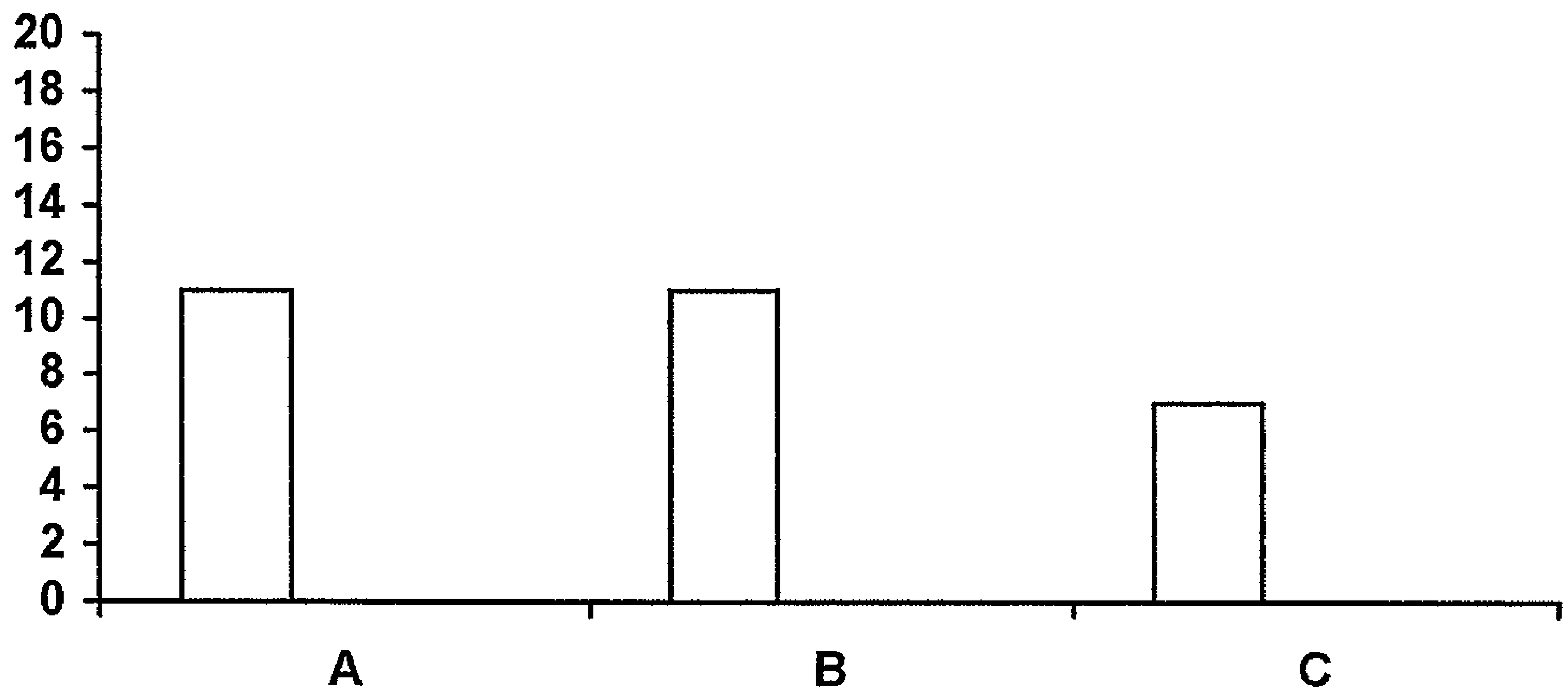

Figure 17 Numbers of correct assessment out of 20 subjects performed by 3 raters at postural position +6mm: A (11/20), B (11/20), C (7/20).

Inter-rater reliability was analysed to establish the degree of agreements amongst 3 observers using Cronbach's alpha. The reliability for all three raters was 0.547. The reliabilities between raters were 0.491 for A and B, 0.387 for A and C, and 0.456 for B and C. Table 4 summaries the reliabilities amongst raters.

Raters	Cronbach's alpha
A, B and C	0.547
A and B	0.491
A and C	0.387
B and C	0.456

Table 4 Inter-rater reliability using Cronbach's alpha.

DISCUSSION

The occlusal vertical dimension (OVD) and its implications in restorative dentistry, especially in full mouth rehabilitation, have been studied for many decades since the early investigation by Thompson (1946). There have been various methods applied to establish the OVD. The postural jaw position (PJP) has been utilized to achieve a clinically acceptable OVD, although the PJP will vary in relation to changes in head position, presence or absence of teeth, loss of teeth, dental attrition, emotional state, the time of recording, and any conditions that can alter the jaw muscle tones. The methods utilized to obtain the PJP are pre-extraction records, phonetics, aesthetics, swallowing, and EMG, although most clinicians tend to utilize more than one method to determine the PJP.

The previous EMG studies on jaw muscles in relation to the PJPs were mainly focused on the masseter and temporalis muscles due to relatively easy identification and accessibility. The mentalis muscle has not been considered by clinicians as an aid for establishing the PJP, although the muscle has the crucial role of supporting the lower lip and the position of the incisor teeth (Ballard 1953).

This study was designed to evaluate the efficacy of two methods of assessing the changes in PJP in dentate subjects. The first method was to investigate increases in the mentalis muscle activity in relation to varying PJPs. The second method was to visually evaluate through the assessments of clinical photographs, the efficacy of observation of changes in the mentalis muscle by the varying PJPs.

The PVD which played a role as a reference position in this experiment was determined by combinations of phonetics and visual observations of the chin tension of the mentalis muscle. The effect of a splint in the mouth was also investigated, prior to comparing EMG recordings on the mentalis muscle at increased vertical dimensions from the clinically determined PVD.

EMG recordings were compared between the PJP with and without a splint. The analysis showed that there were significant differences in EMG on the mentalis muscle between PJP with and without a splint. The EMG with a splint resulted in higher activity than without a splint. One possible explanation for this is that although the splint was trimmed not to interfere with any jaw movements or discomfort of the subject and the thickness of the splint was kept minimal (0.8mm), placing a splint in the mouth could stimulate the spindles in jaw muscles, or receptors of the temporomandibular joints.

Carlsson et al (1979) compared EMG activities of the masseter, anterior, and posterior parts of temporal muscle immediately before and after inserting a splint; interincisal clearance was 4mm in the incisal region, and found that the EMG activity in the posterior part of the temporal muscle did not change significantly upon placement of the splint; activity in the anterior part of the temporal muscles decreased; activity in the masseter muscle without a splint was very low and tended to decrease further when the splint was placed. Their study suggested that the activity of jaw muscles showed various degrees depending on the muscles, although the muscle activity tended to decrease with a splint. This is in contrast with the current study that found the activity in the mentalis muscle increased when a splint was inserted. Carlsson et al (1979)'s study did not include the mentalis muscle.

Another possible explanation for this significant difference in EMG activity with and without a splint may be that transferring interocclusal distance on the articulator using an arbitrary hinge axis could affect the jaw position which might alter the mentalis muscle activity.

Morneburg and Proschel (2002) investigated the effect of transferring of casts in relation to an arbitrary hinge axis instead of a true hinge axis by measuring occlusal errors with 2- and 4mm changes of vertical dimensions. They concluded; if changes of vertical dimension did not exceed 2mm, the transfer of casts in relation to an arbitrary axis induces only negligible errors within clinically acceptable limits.

The interocclusal distance (IOD) of subjects of this study ranges 1-4mm (amount of vertical openings on the articulator), this means that there might be obvious changes of jaw position in some subjects which result in the differences in muscle activity between with and without a splint in the mouth.

EMG recordings from the mentalis muscle for each subject were pooled at different vertical dimensions, and the mean values of EMG activity showed that the activity in the mentalis muscle was increased subsequently from PP without a splint, PP with a splint, PP+2, PP+4, to PP+6mm, which had a RMS range from 0.0767 to 0.2359. When comparing the muscle activity amongst positions with a splint, The RP showed a minimal value and the activity increased with the increased vertical dimensions, and the analysis showed that there were statistically significant differences between the positions with a splint. However, the EMG activity in mentalis muscle showed the lowest value at PP without a splint. From this study, the mentalis muscle has a specific vertical dimension of minimum EMG activity of each subject, which is the PVD. This result agrees with those of Rugh et al (1979) and Manns et al (1981). Manns et al (1981) found that the gradual decrease of EMG activity in jaw muscles (anterior, and posterior temporal and masseter muscles) from the intercuspal position (IP), passing through a range of maximum reduction at a certain interocclusal distance, and gradually increasing to the highest values close to maximum jaw opening, which demonstrated that there is a certain vertical dimension of minimum muscle activity of each subject. Contrary to Manns et al (1981)'s study, Garnick and Ramfjord (1962) claimed that there was an area of constant minimal EMG activity for the same jaw muscles which were called "resting range". Above three studies were devoted to the same jaw muscles although there was no investigation done for the mentalis muscle.

The observations of changes in chin contour and tension of the skin of the chin are clinically useful signs when deciding whether the lips are artificially pulled together from the determined PVD. Since these signs are related with the function of mentalis muscle, this study was focused on the mentalis muscle, and whether if it is feasible to detect changes on the muscle with varying PVDs. An overall view of the observations by 3 raters with different clinical experience levels indicates that the visual methods used to detect the changes in the chin are not reliable. The current study shows that the raters showed less than 50% accuracy of PVD determination. This result is similar to those of Gross et al (2002), although their study used two groups of observers; dentist and non-dentist. The difference between the two groups was statistically significant with dentists erring less, although the inter-rater reliability was not mentioned in the study. Also their study showed that the changes of face height from 2 to 6mm increase from OVD or PVD were not apparent on facial appearance, and they postulated that it might be due to facial soft tissue compensation for changes in lip and tone of mentalis muscle.

In this study, each rater did not exhibit significant differences in correct assessments for each position. This can partly be explained in that amounts of increasing PVD did not exceed 6mm from the clinically determined PVD.

The three raters have different levels of clinical experiences in dentistry, and the inter-rater reliability expressed in Cronbach's alpha was lower than the widely accepted cut –off (0.7). In conjunction with the low percentages of correct assessments, this may suggest that there were difficulties for raters in detecting the changes of the contour and tension of mentalis muscle on the clinical photographs. The subjects volunteered for this study are different in gender, race, facial form and skin tone. Also, the age range was 23 to 67years, although all have sufficient number of teeth to establish a stable occlusion. In dentate patients, aging of the skin is related with soft tissue changes (Barglett et al 1992). These lead to various degrees of thinning, wrinkling, and sagging and laxity of the facial skin, and they depend on age, gender, race, facial form and individuals. These diversities could contribute an individually different reaction of skin tone to changes in OVD and PVD, which could make it difficult to detect from clinical photographs. Also, 3 basic facial forms; mesofacial, dolichofacial, and brachyfacial form possess occlusal planes for different lip supports and vertical dimension discrepancies (Mack 1991). For example, the mesofacial form is characterized by a harmonious relationship of the vertical and horizontal facial planes, and has an ideal occlusal plane for lip support. In contrast, the dolichofacial type has an excessive vertical dimension relative to horizontal dimension of the face. The facial forms may contribute to differences in the extent of visually detectable skin tension with varying vertical dimensions.

Tosello et al (1998) recorded EMG activity of orbicularis oris and mentalis muscles in children, which were subdivided into normal group (Class I and normal swallowing and competent lips) and Class II division 1 with atypical swallowing and /or incompetent lips. In the "rest" position with lips separated, both groups showed no activity in any of muscles. Although when lips were in contact, muscle activity was recorded in the subjects with incompetent lips. They also found marked muscle activity of orbicularis oris and mentalis muscles was recorded in the movement of sucking in the subjects with incompetent lips.

In the current study, the subjects were not sub-classified according to the above mentioned characteristics.

This study was a pilot study to determine the efficacy of an empirical method utilized as an aid to determine the PVD for partially or completely edentulous patients. The subjects were limited in sample size and were all dentate with no need for establishing a new PVD. Goldspink (1976) concluded that changes in ICP result in changes in PJP and IOD in dentate individuals, because jaw muscle length at tooth contact determines postural jaw muscle length as well as maximal bite force muscle length. However, in fully or partially edentulous cases where there is no stable occlusion as a reference position, the postural muscle length is used to determine the OVD. So, it would be more clinically relevant in future investigations to include subjects who require establishing a correct PVD before an initiation of any restorative dental treatments, and to see if any differences found when determining a new PVD in such cases.

CONCLUSIONS

This study compared the efficacy of utilizing the contour and tension of the chin to determine a correct PVD visually, and compared electromyographic recordings from the mentalis muscle. This pilot study led to the following observations.

The mentalis muscle activity was minimal with PJP induced by a combination of phonetics and visual observation of the mentalis muscle, without the splint in position. The difference in muscle activity between PJP with and without the splint was statistically significant. This change with use of the splint clearly indicates the effect that an intraoral appliance has on a receptive feedback form the mouth to the trigeminal systems in influencing motor control of jaw muscles.

The mentalis muscle activity was increased gradually from PJP with the splint, PJP + 2, +4, to +6mm.The difference in muscle activity between the positions was statistically significant.

Assessing the clinical photographs to identify differences in vertical dimensions by 3 different clinicians showed low inter-rater reliability (< 0.7) and the percentages of correctness for 3 clinicians were all less than 50%. Therefore, the use of visual observation of the mentalis muscle to determine a correct PJP was not a reliable method within this study.

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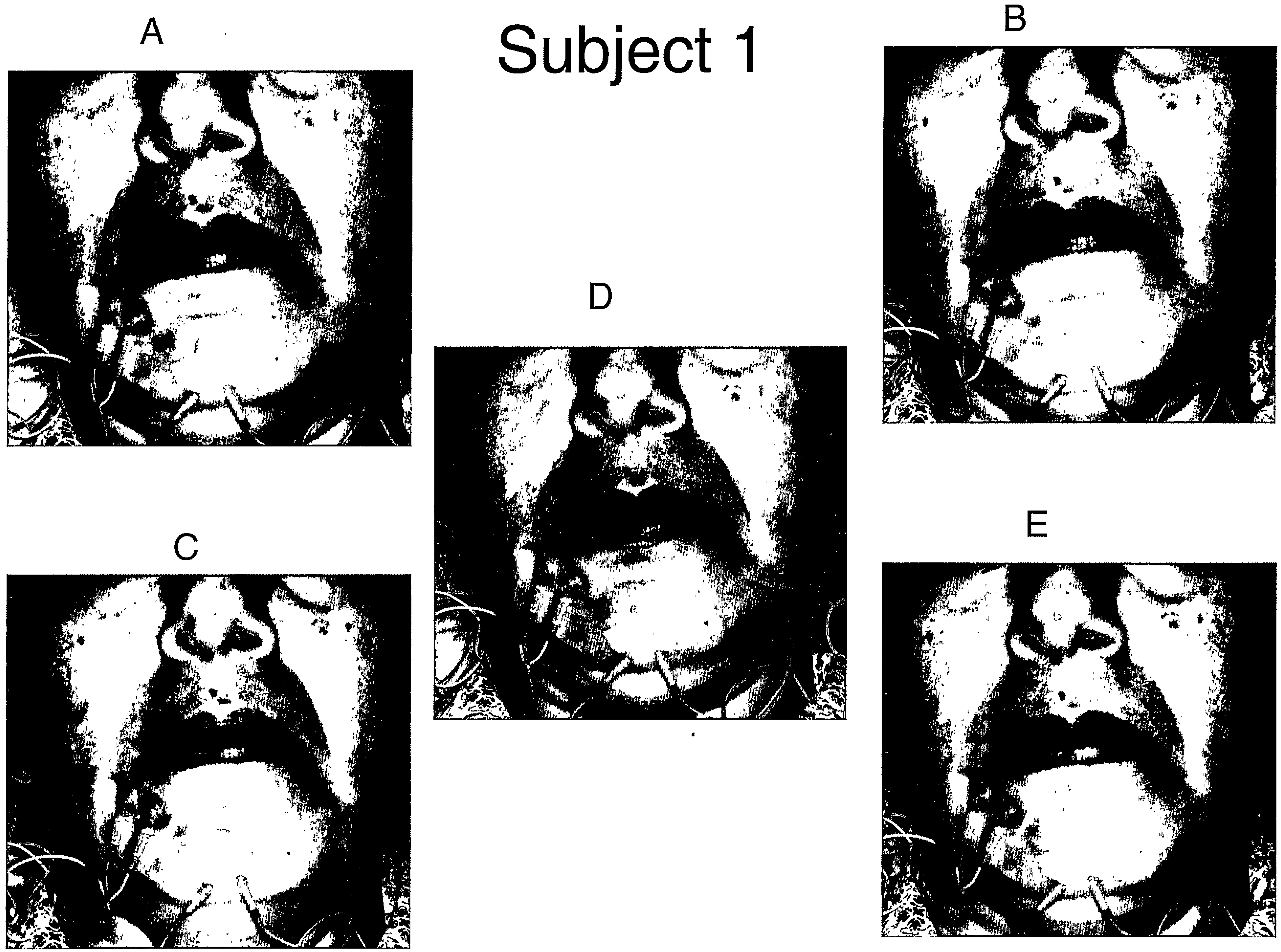
APPENDIX

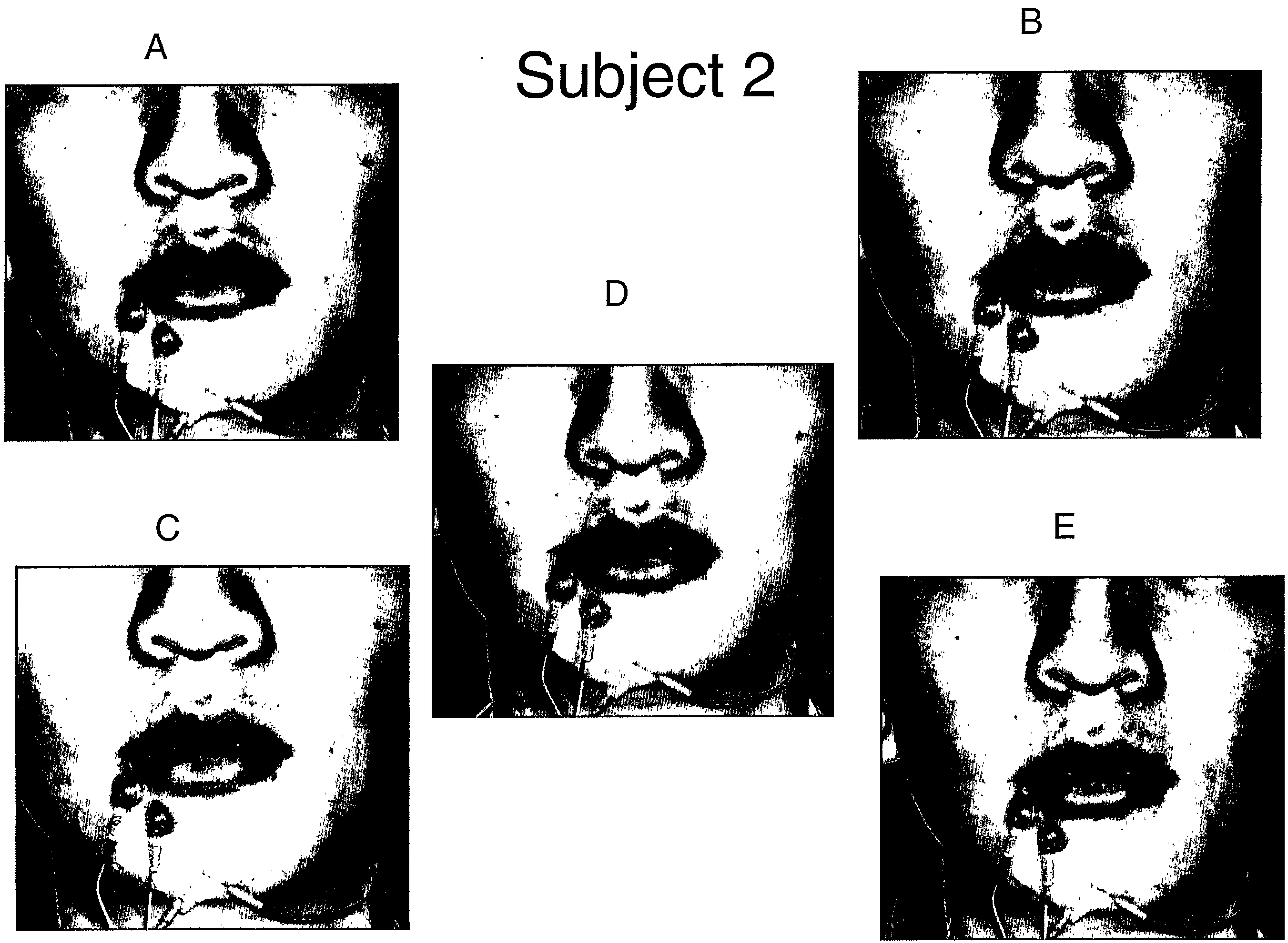
Appendix 1: clinical photographs of subjects

Appendix 2: instruction for assessing the clinical photographs

Subject 1



Subject 2



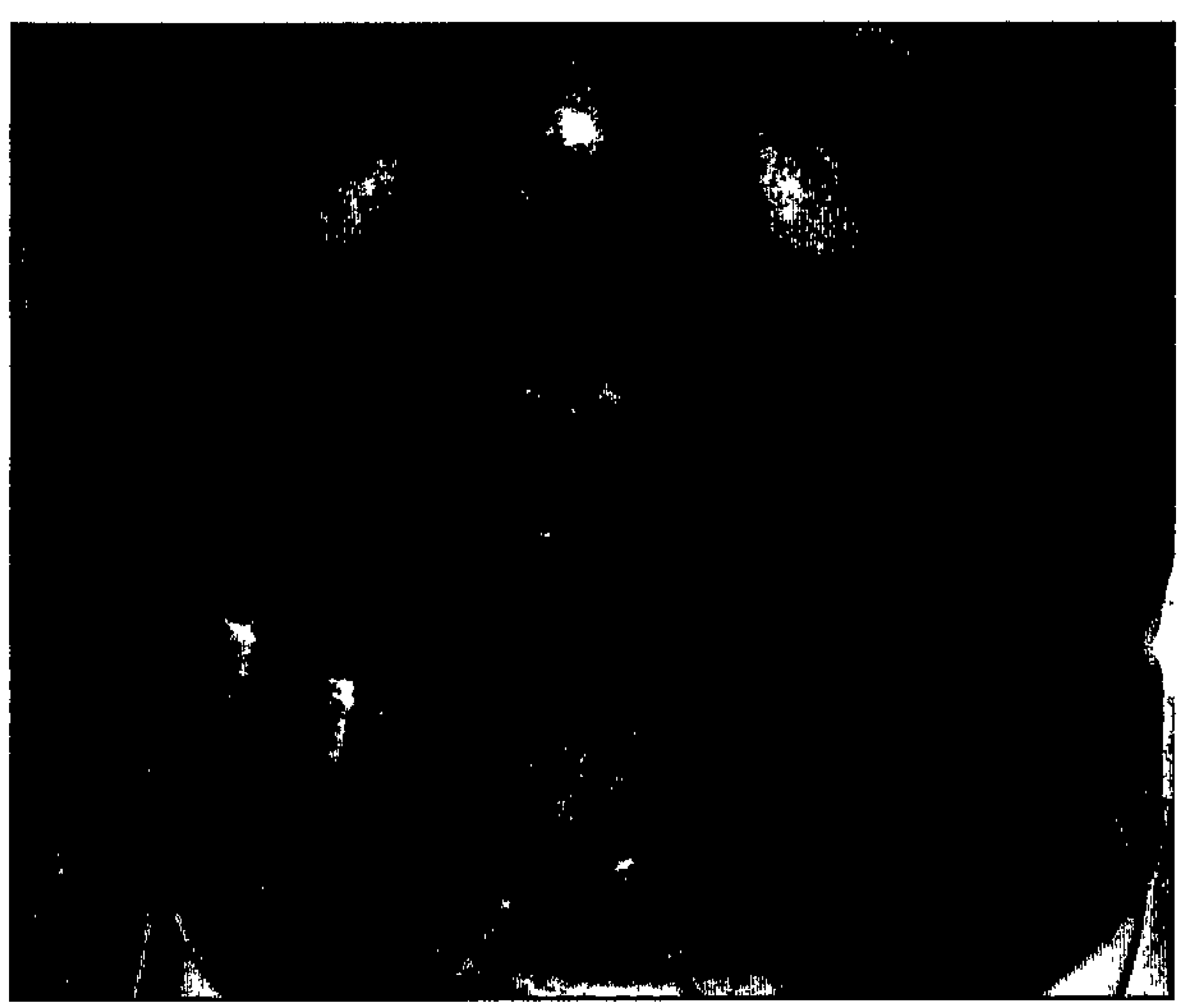
Subject 3

A

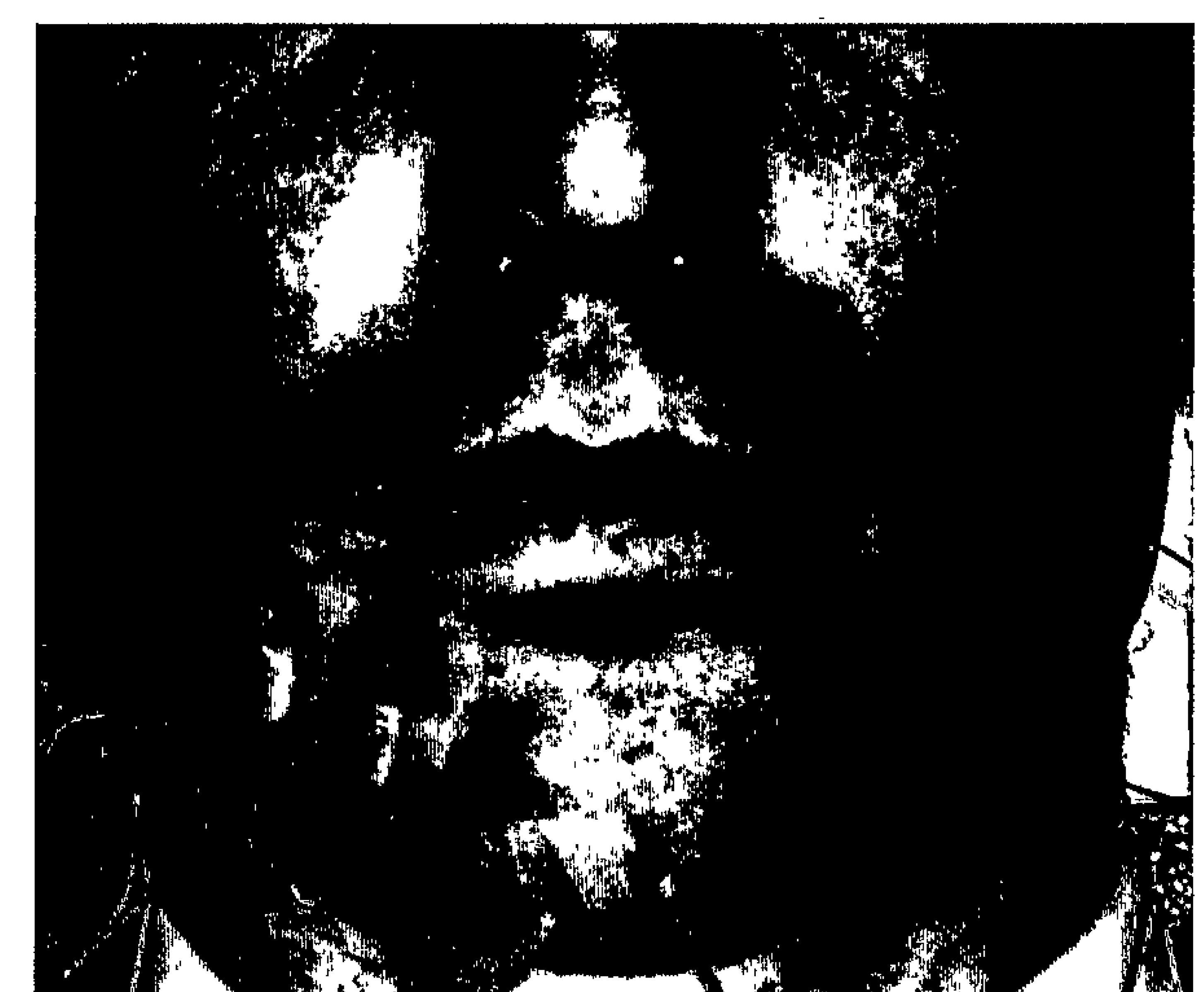
B

D

C



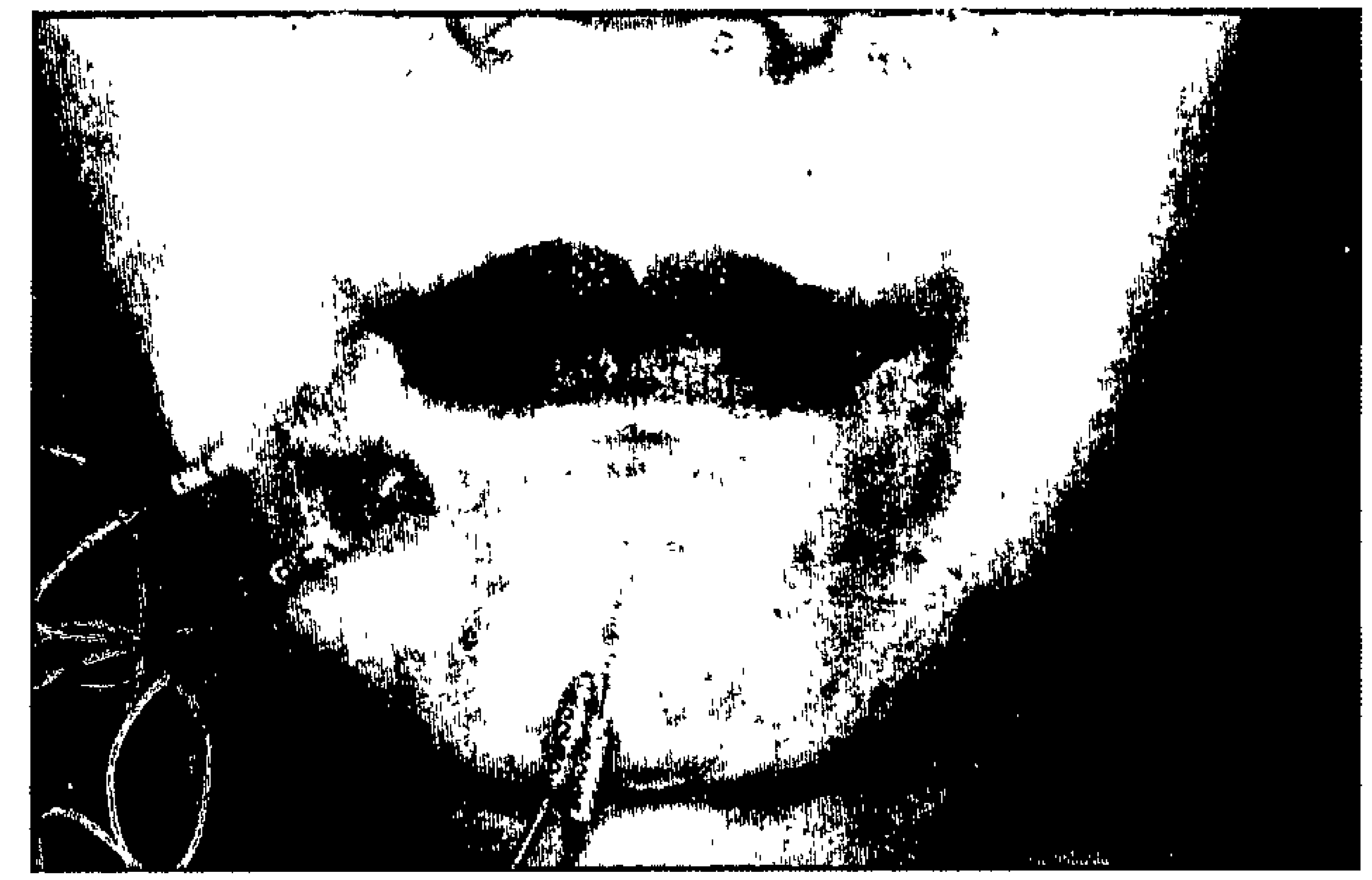
E



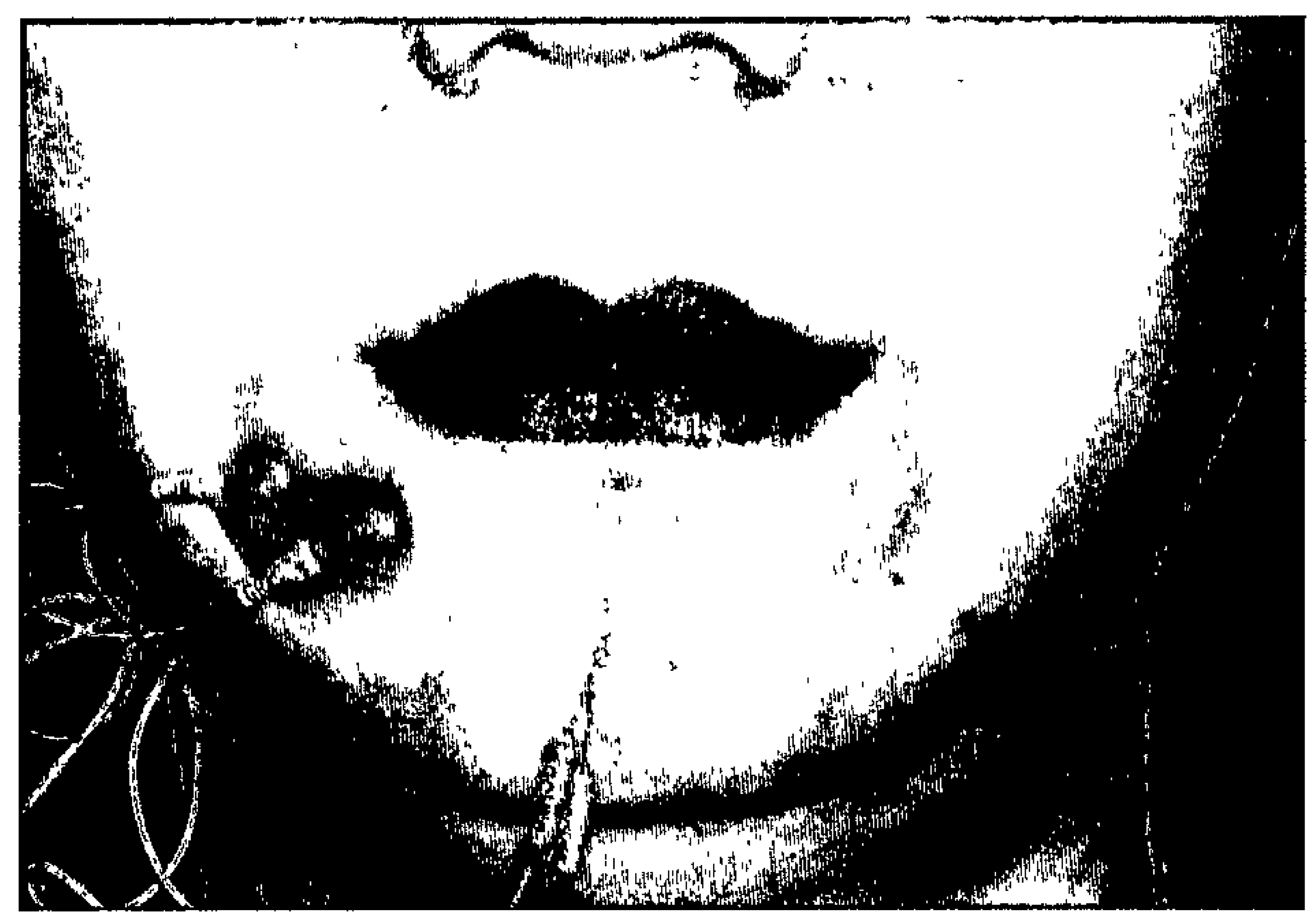
Subject 4

A

B



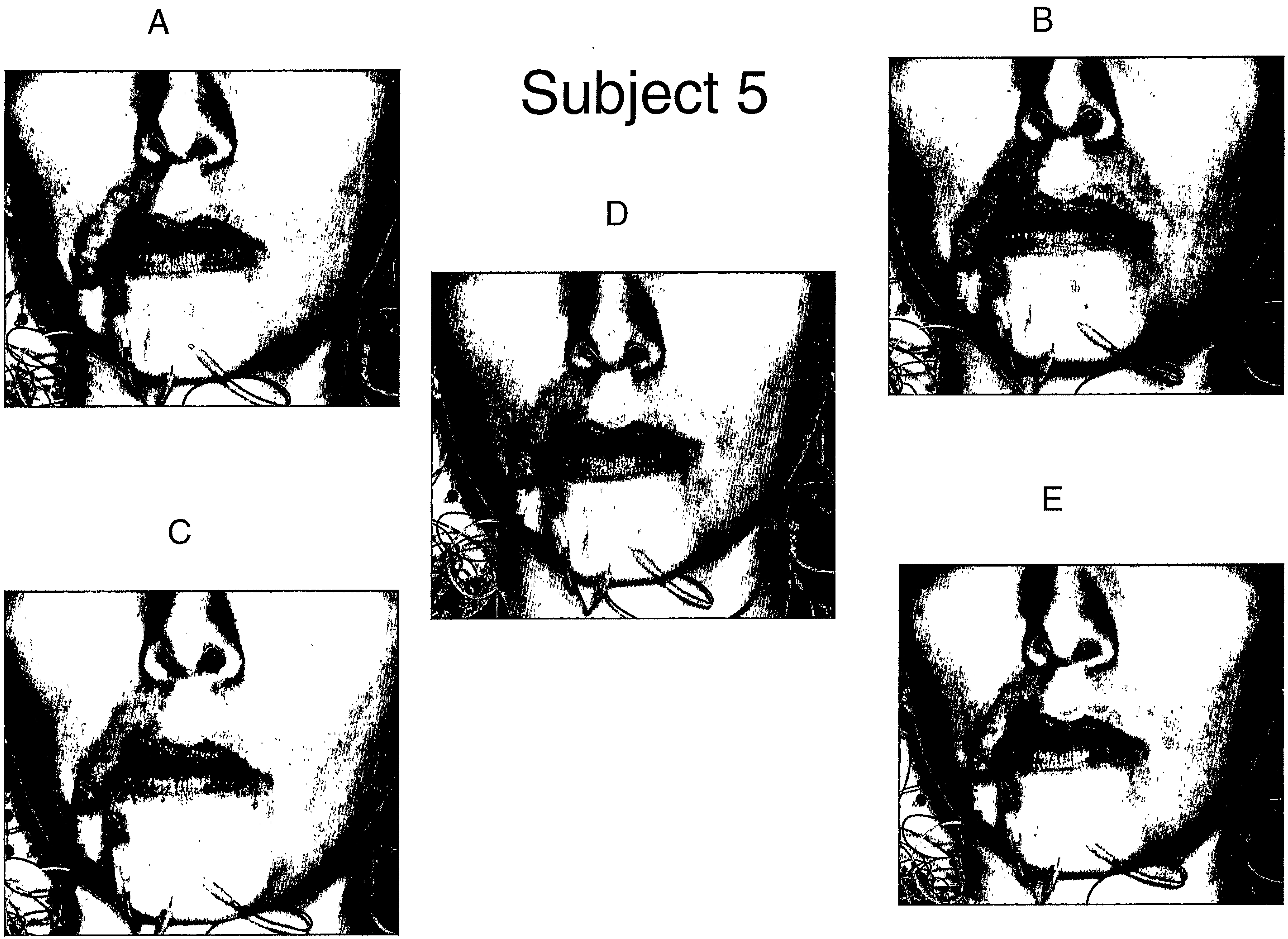
D



C

E

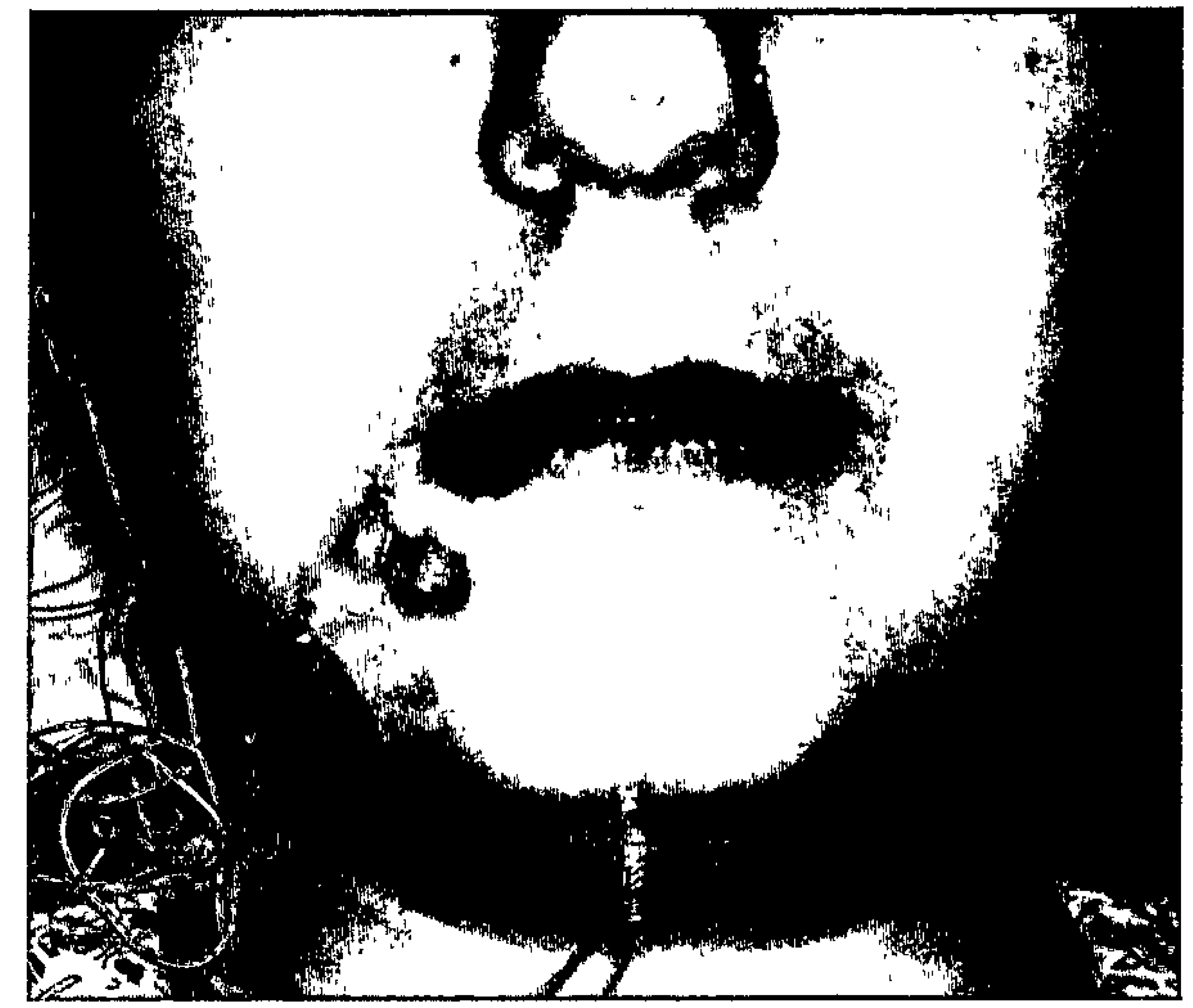
Subject 5



Subject 6

A

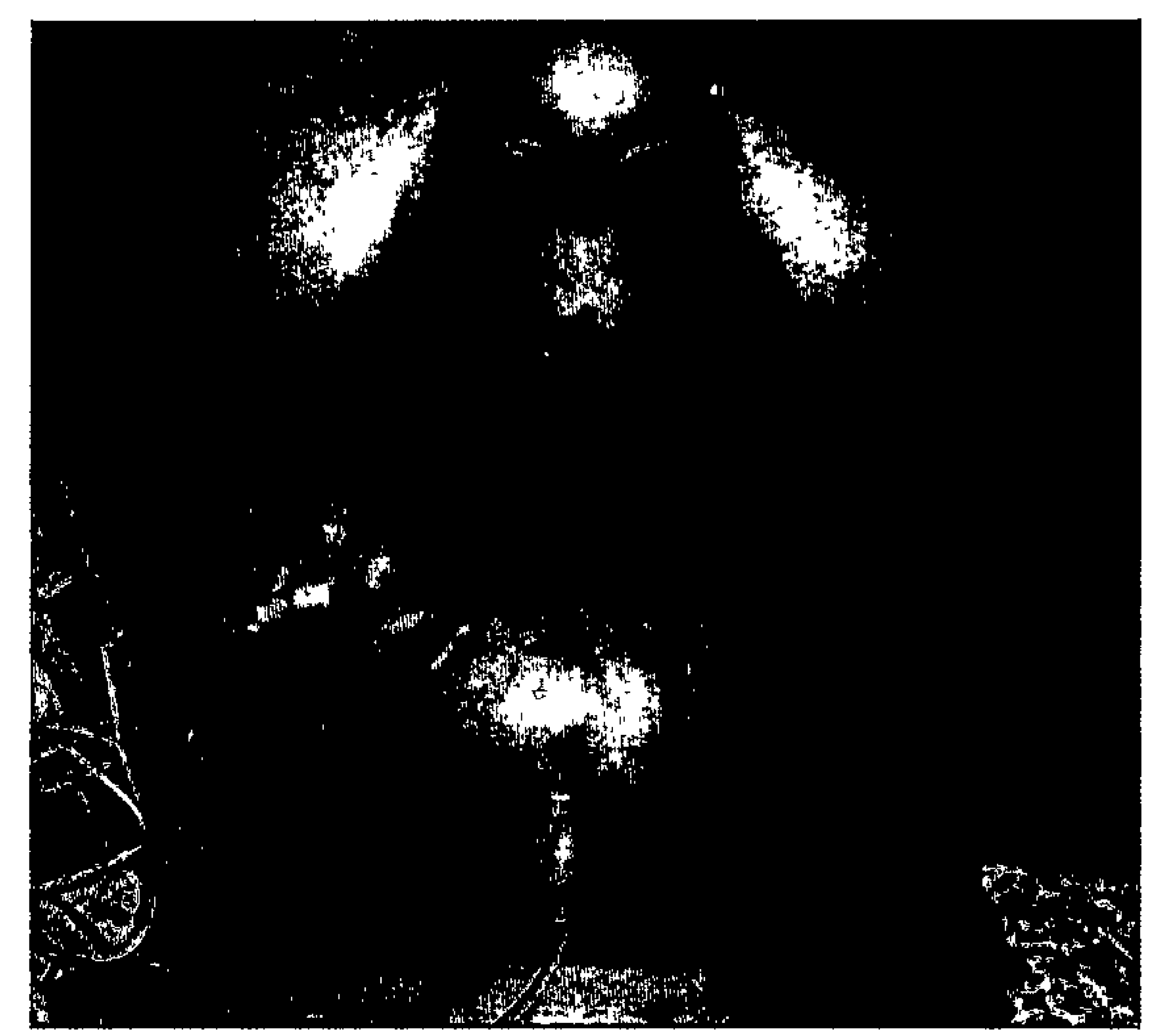
B



D

C

E



Subject 7

A

B

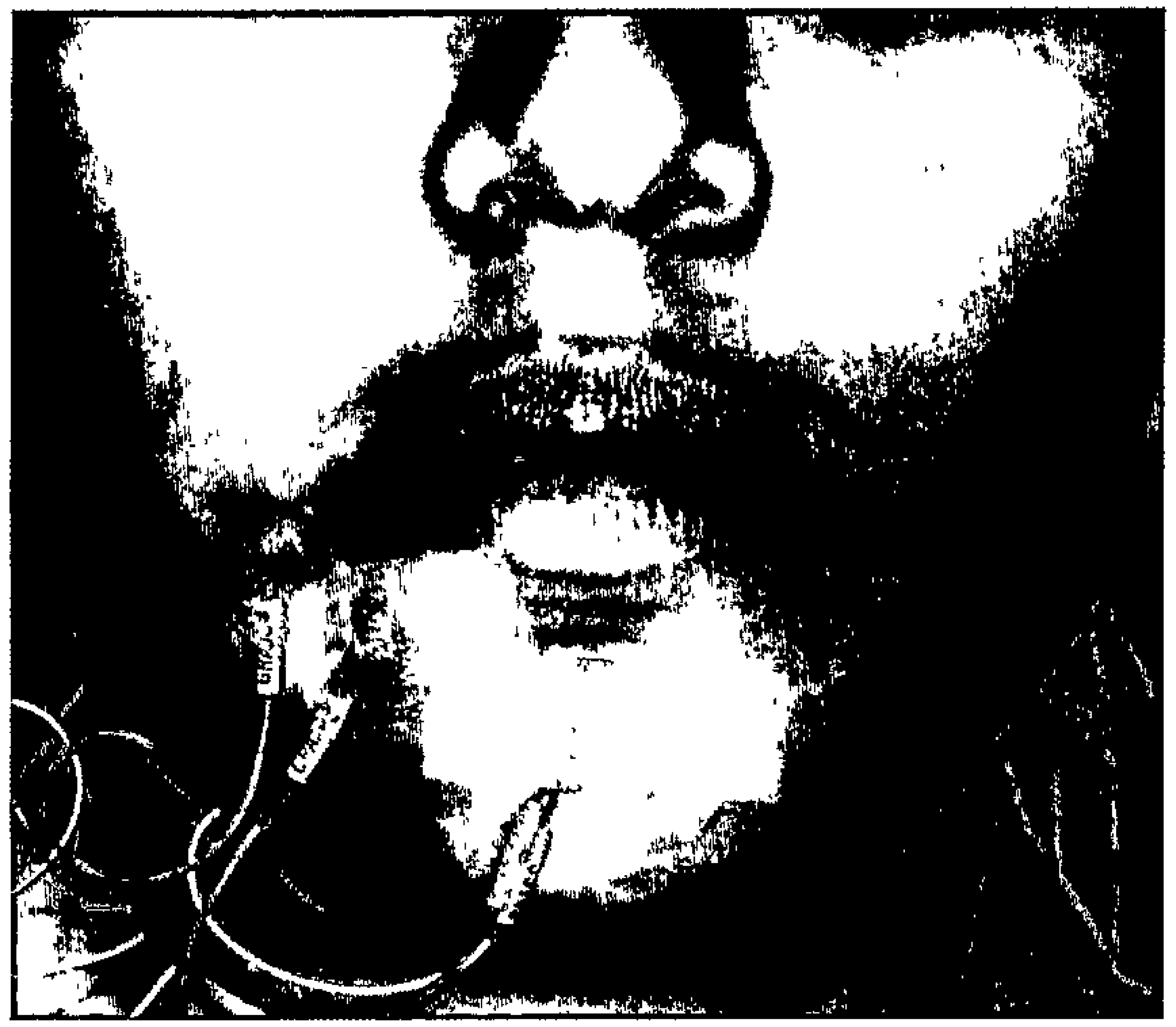
D

C

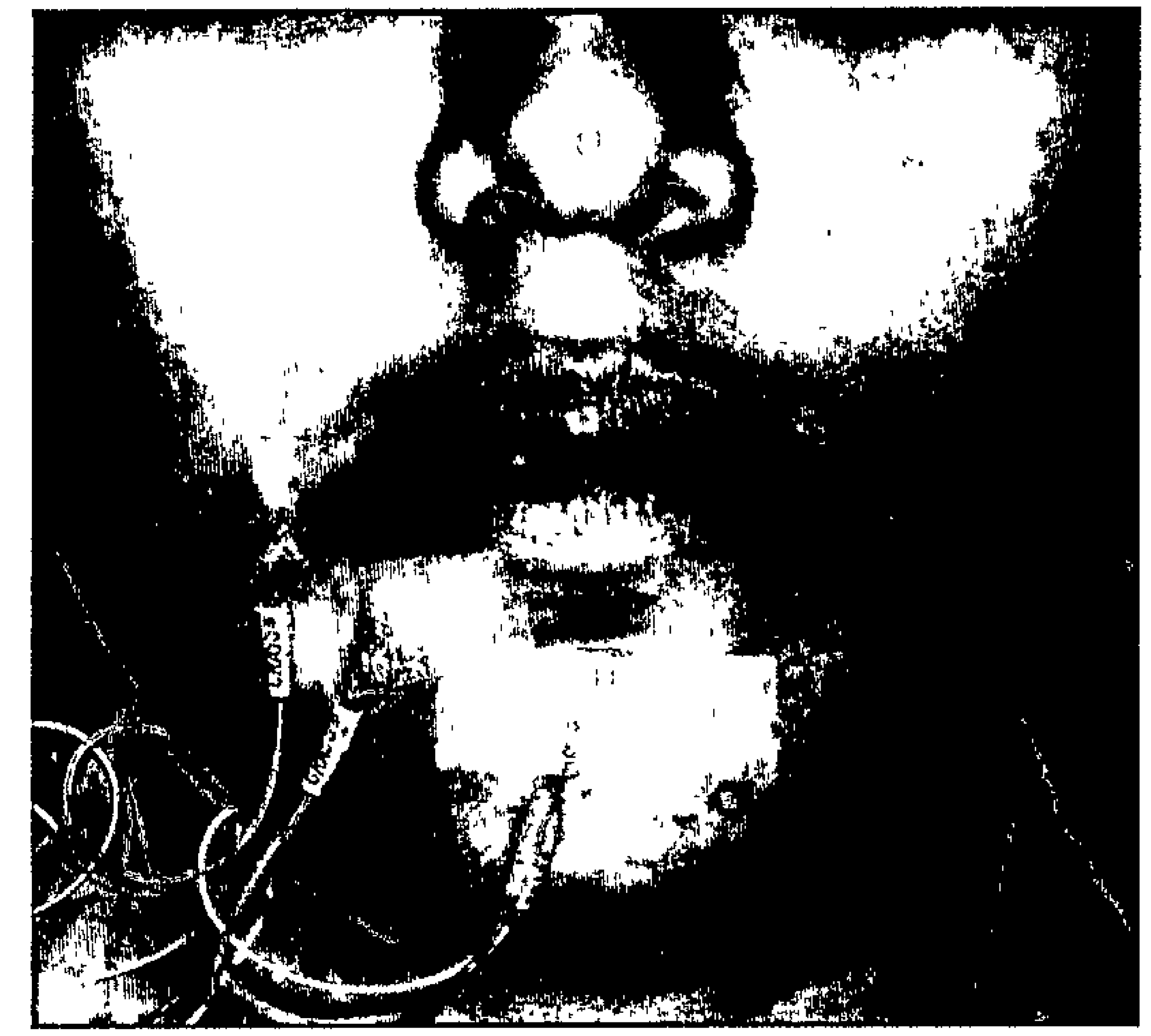
E

Subject 8

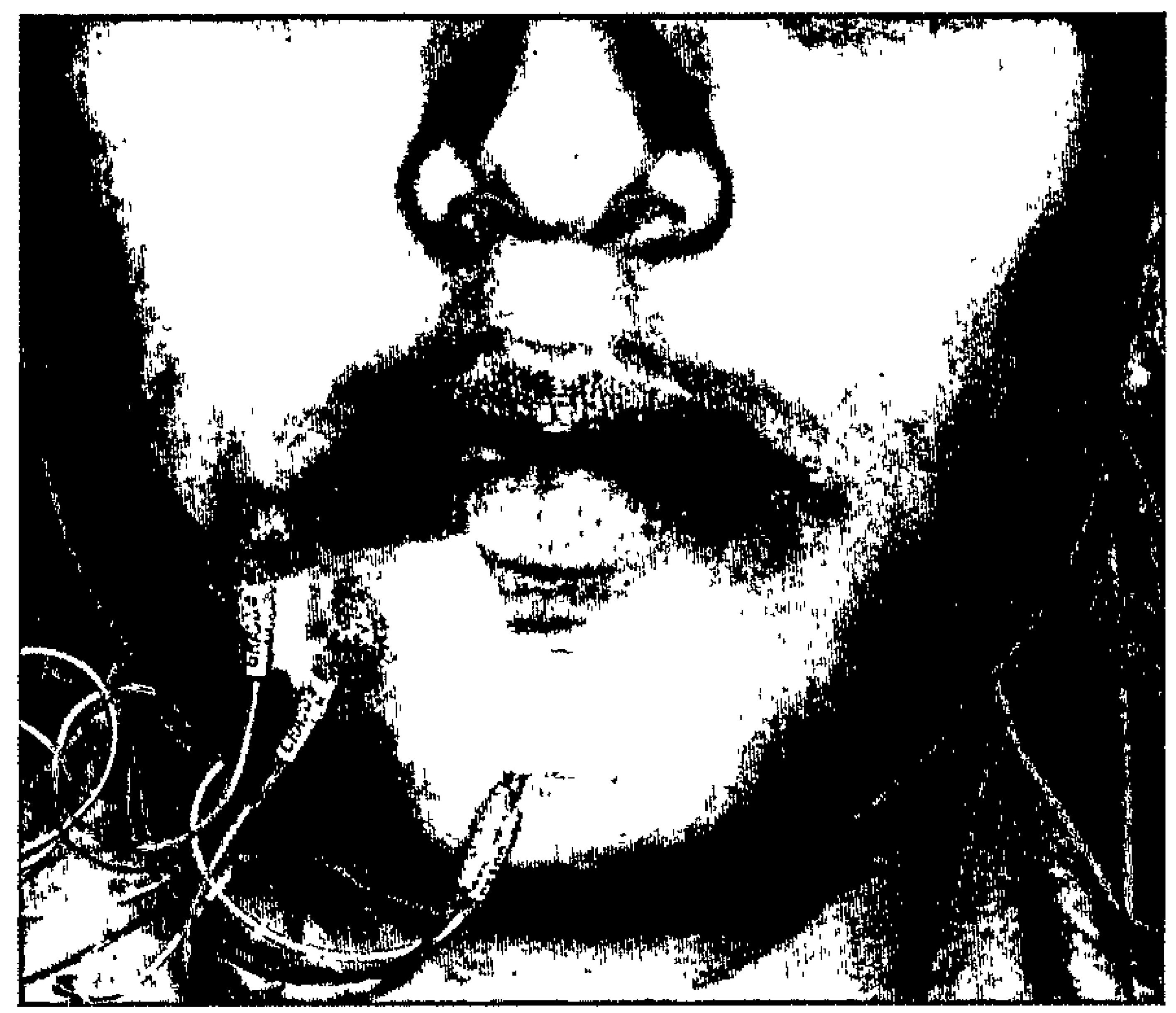
A



B



D



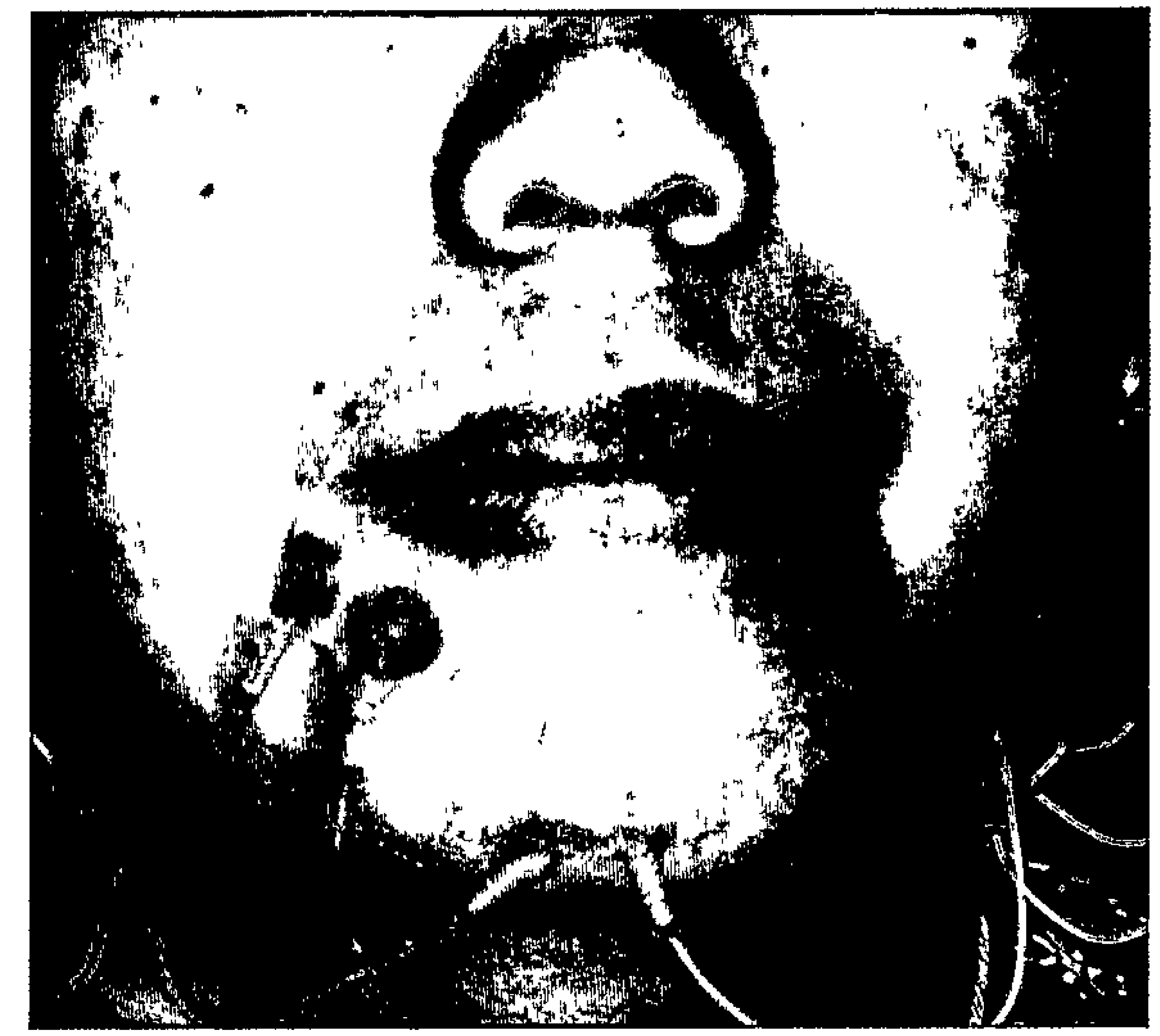
C

E

Subject 9

A

B



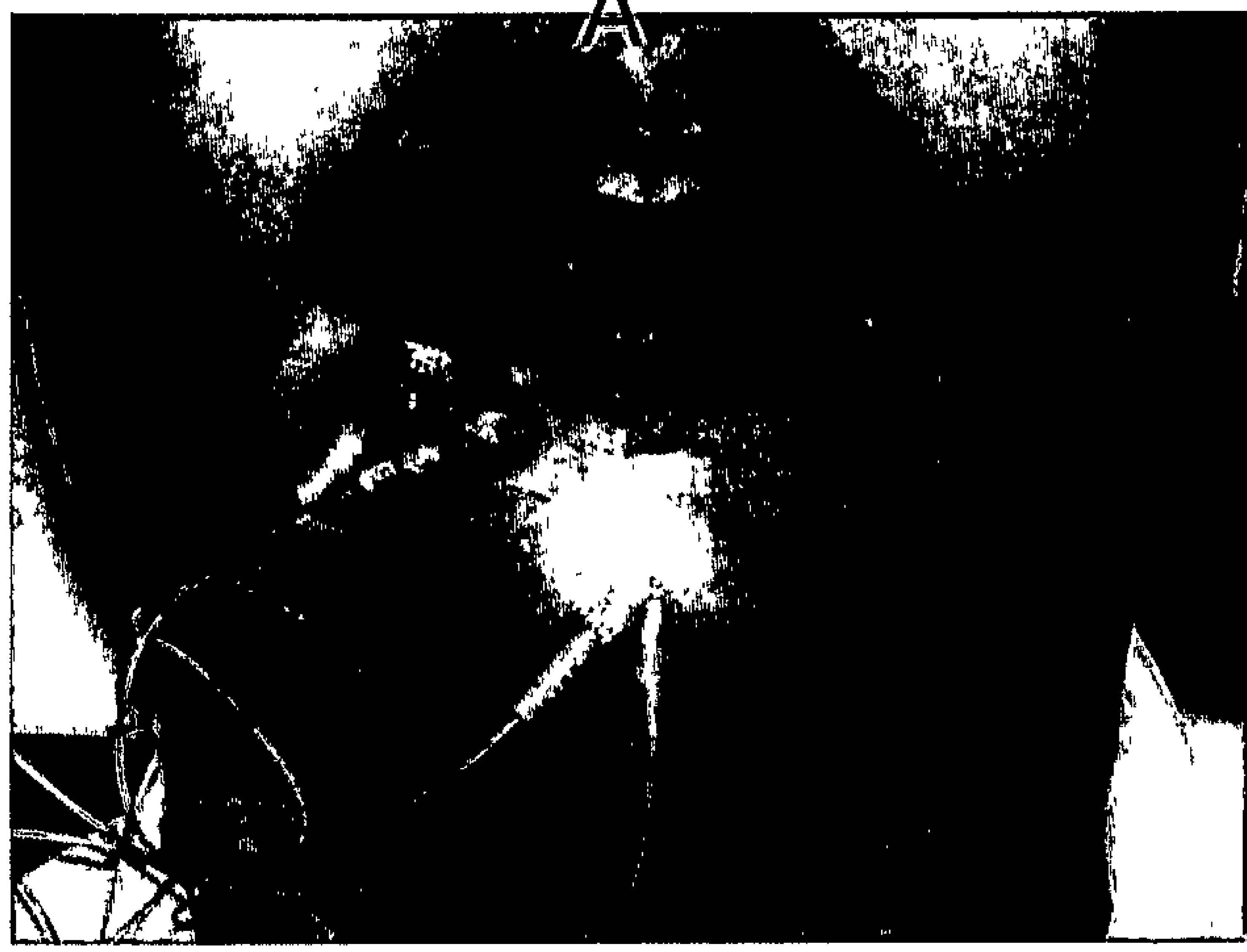
C

D

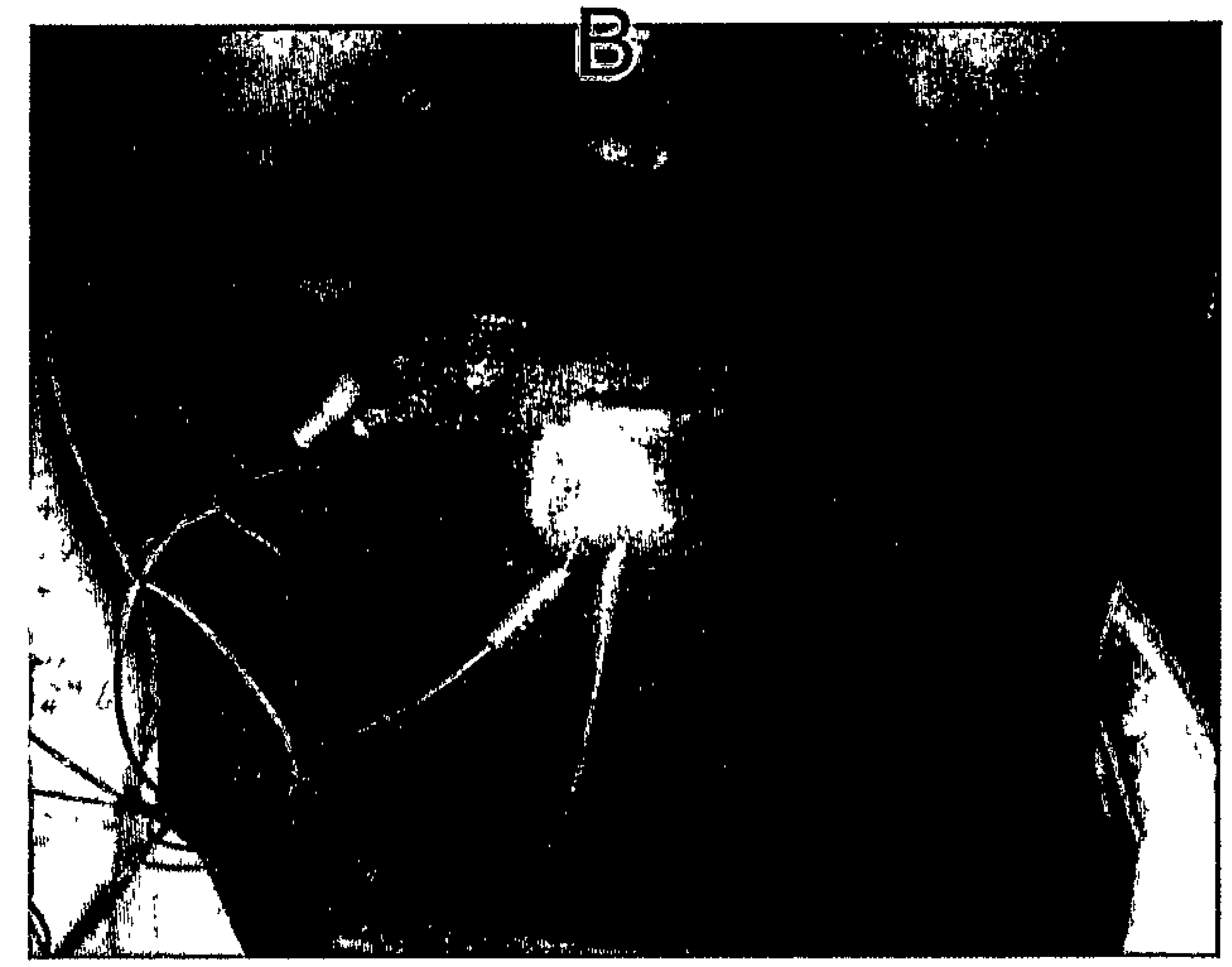
E

Subject 10

A



B



D

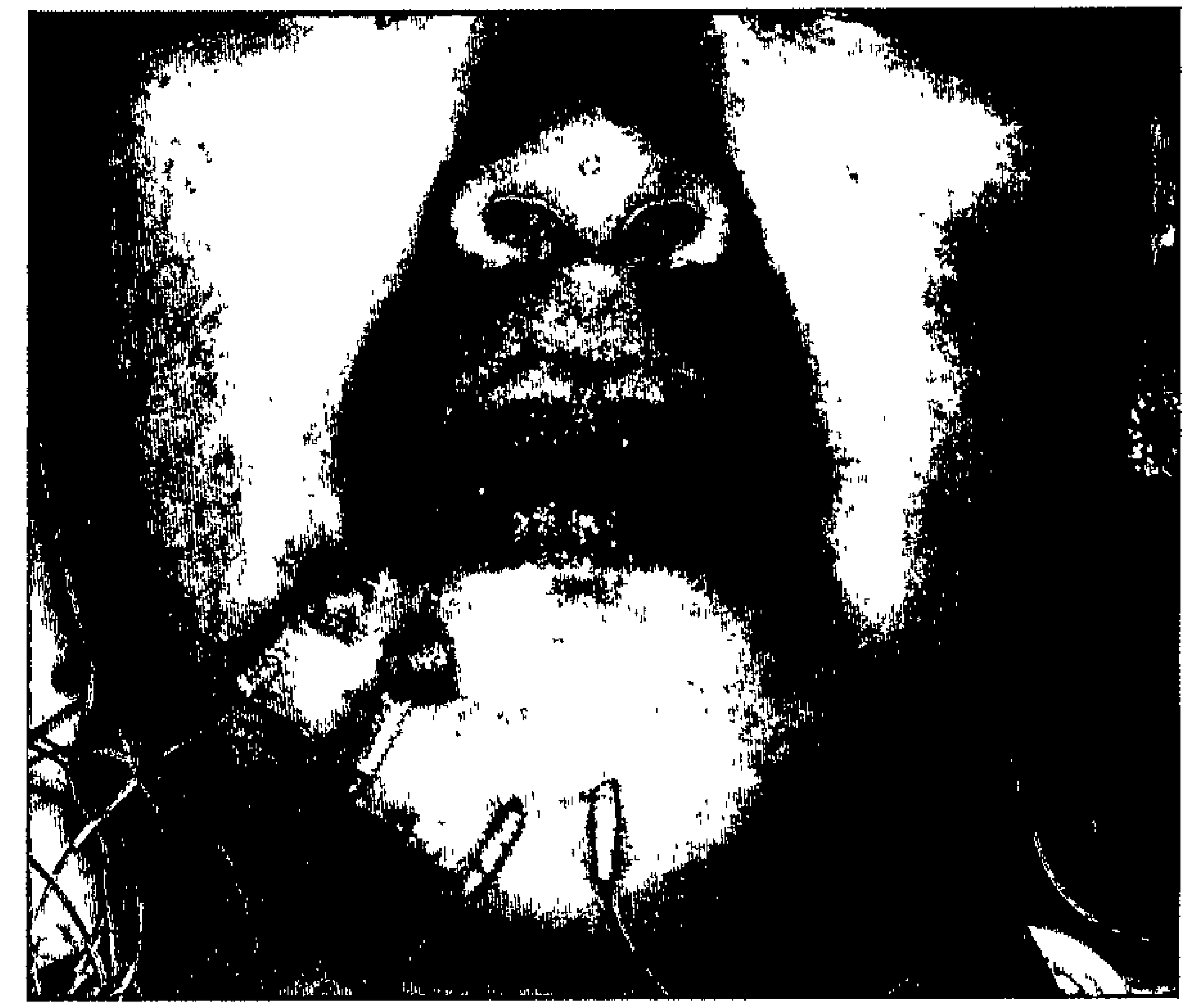
C

E

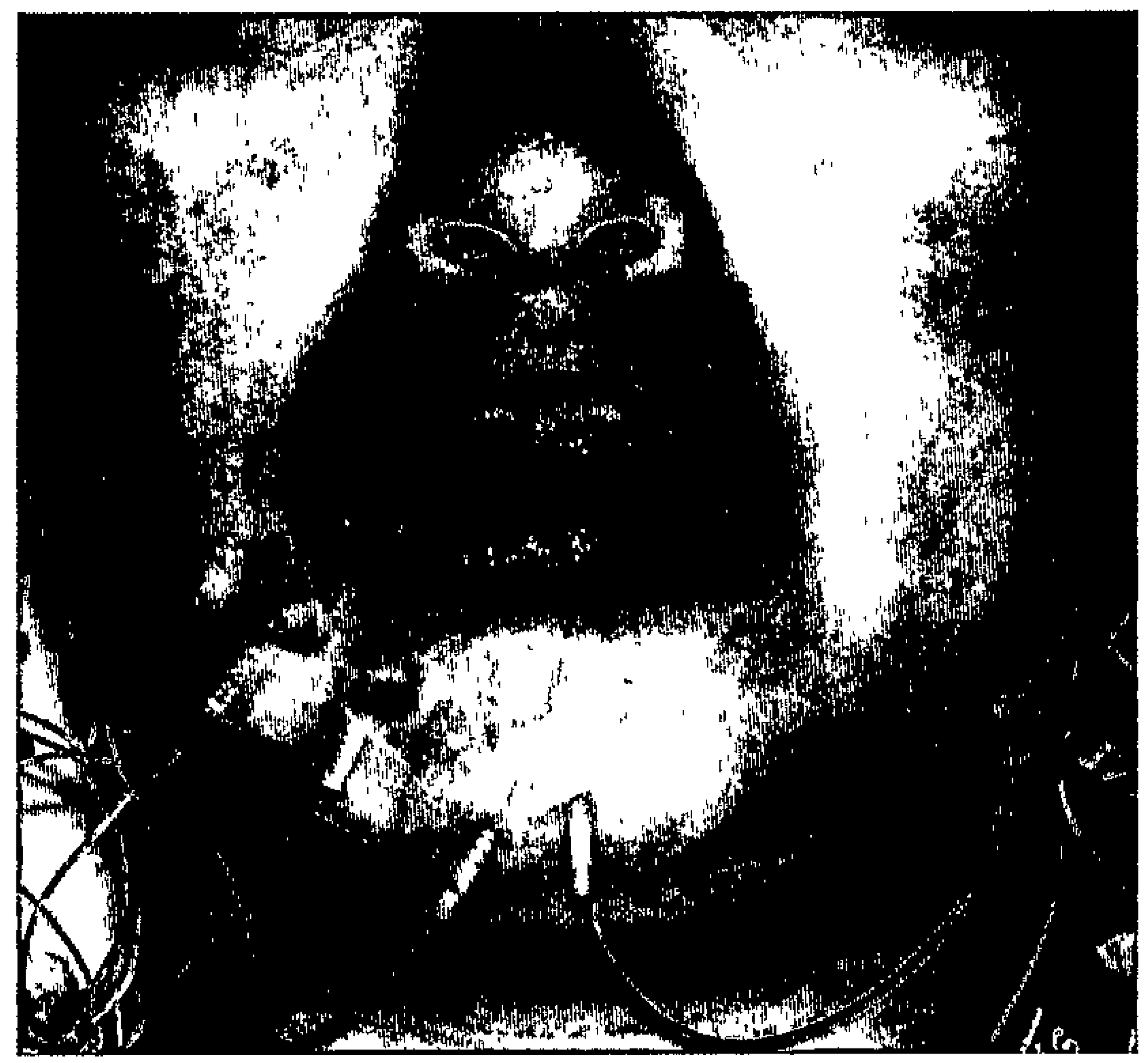
Subject 11

A

B



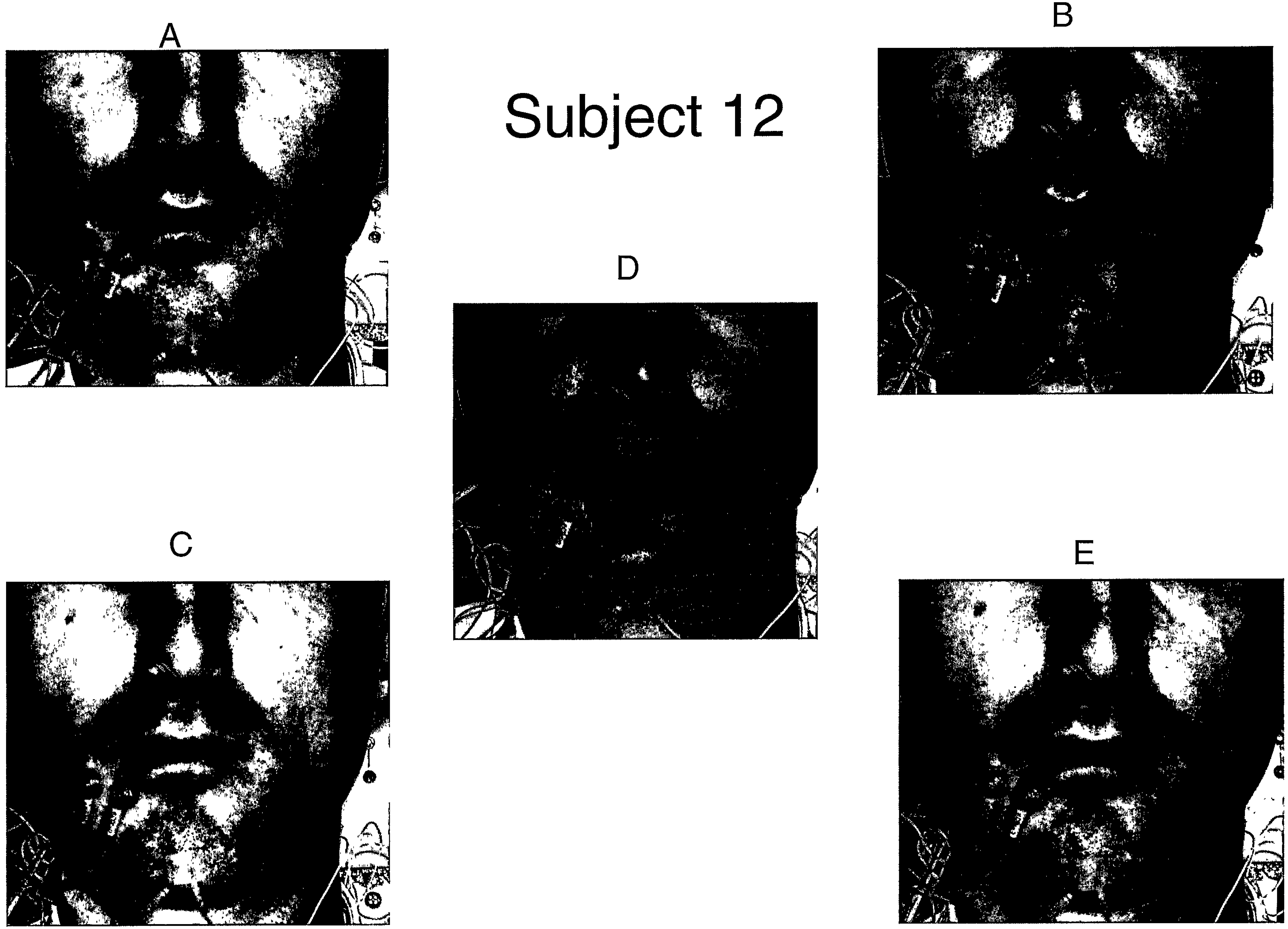
D



C

E

Subject 12



Subject 13

A

B

D

C

E

Subject 14

A

B

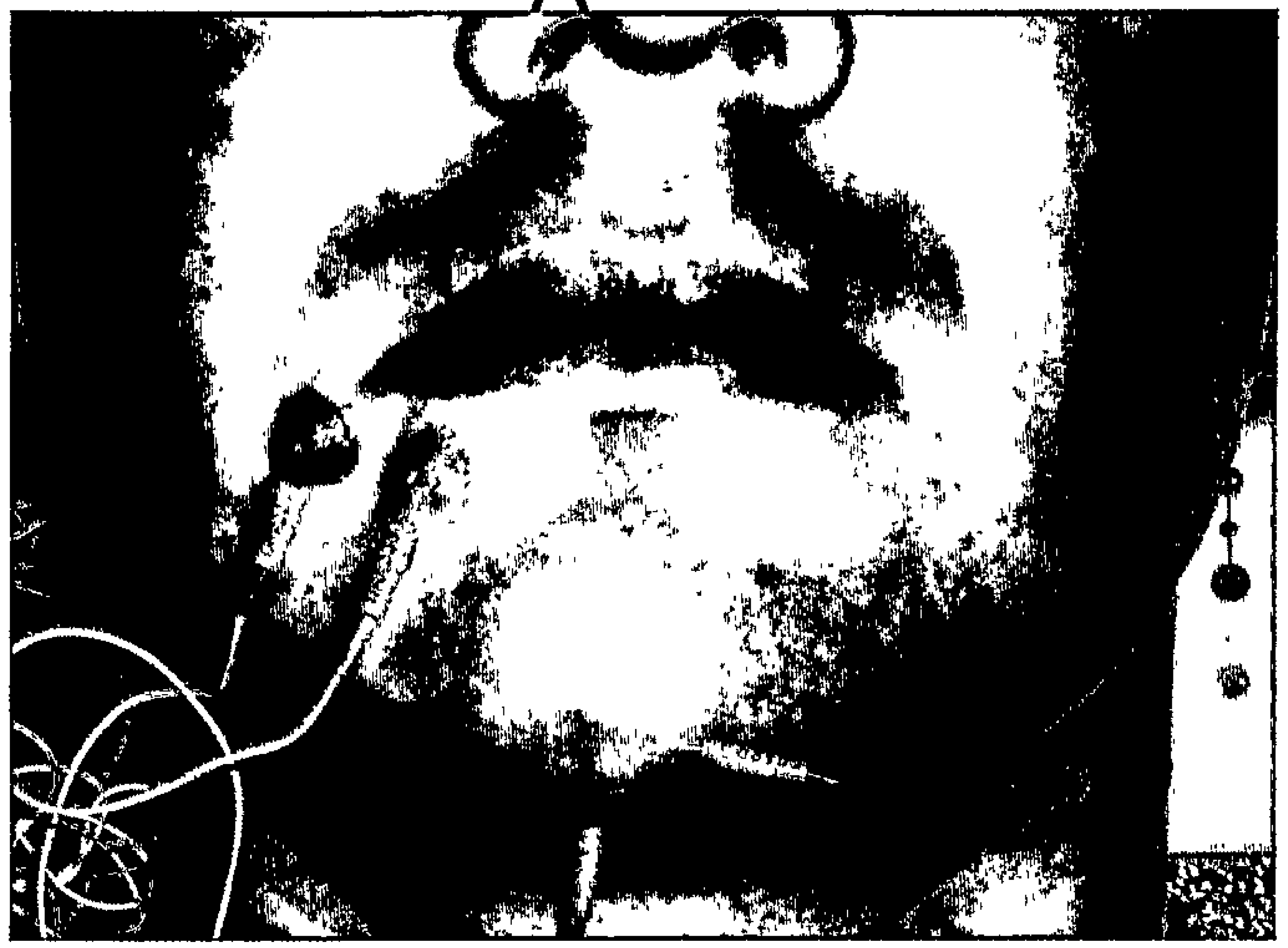
D

C

E

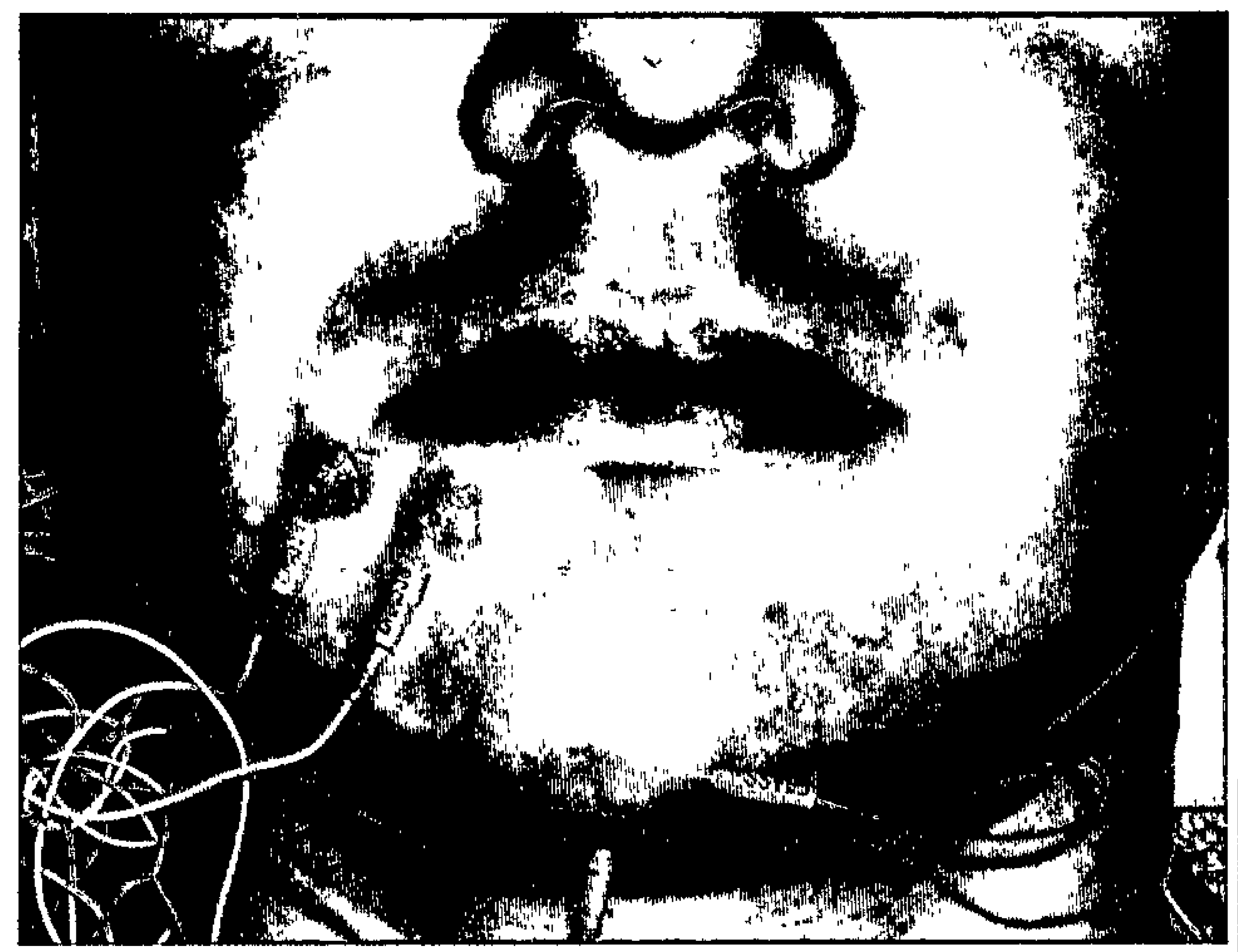
Subject 15

A

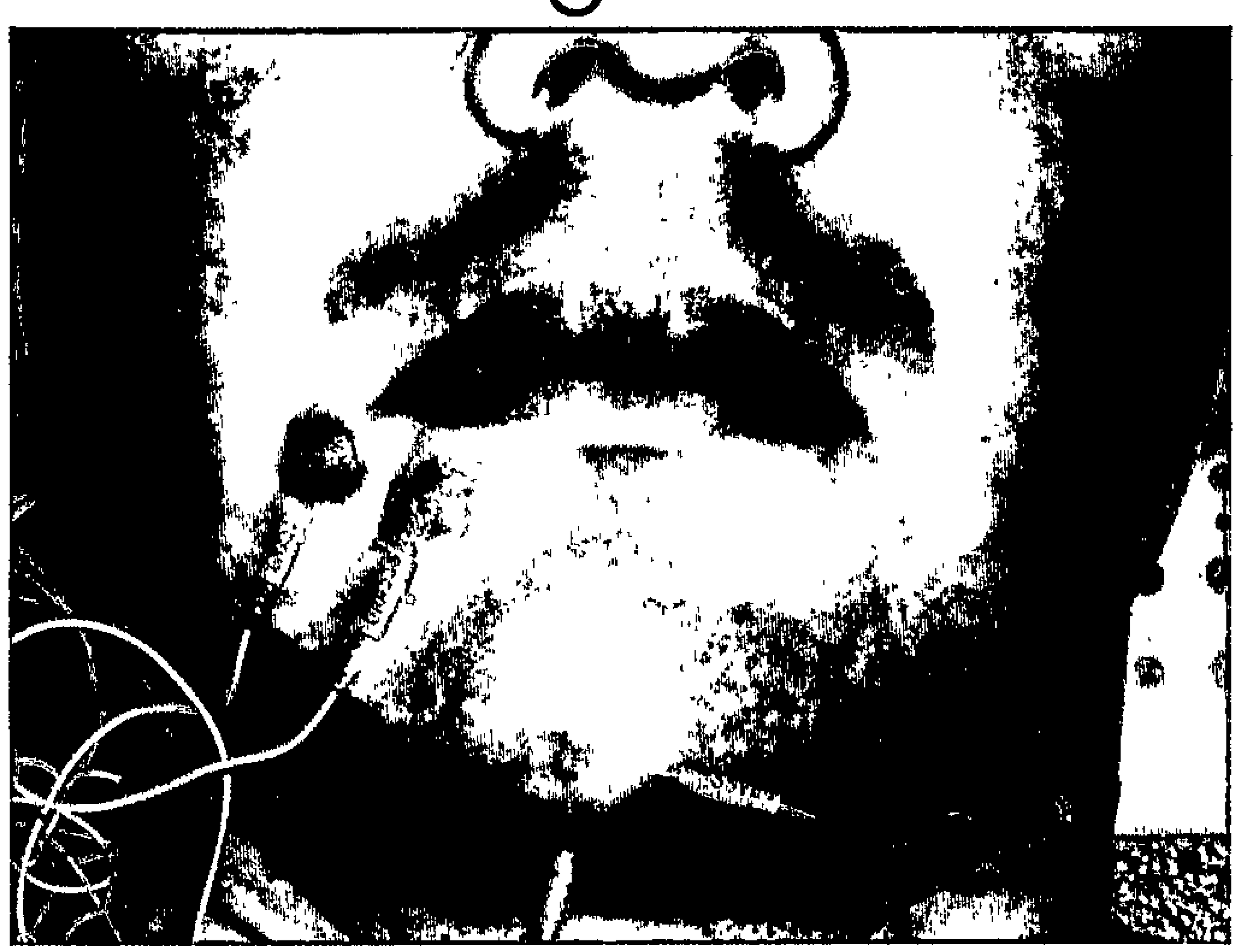


B

D



C

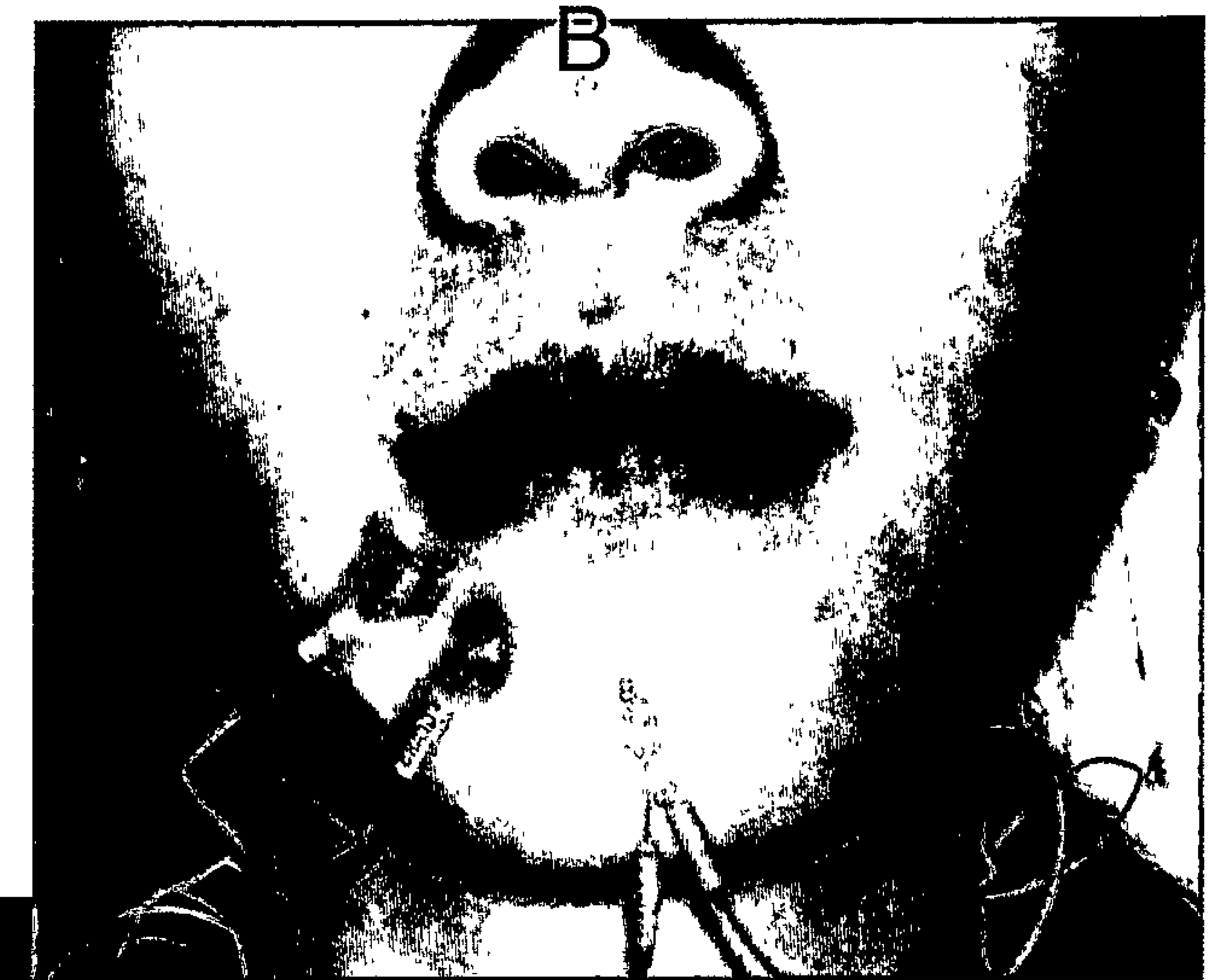


E

Subject 16

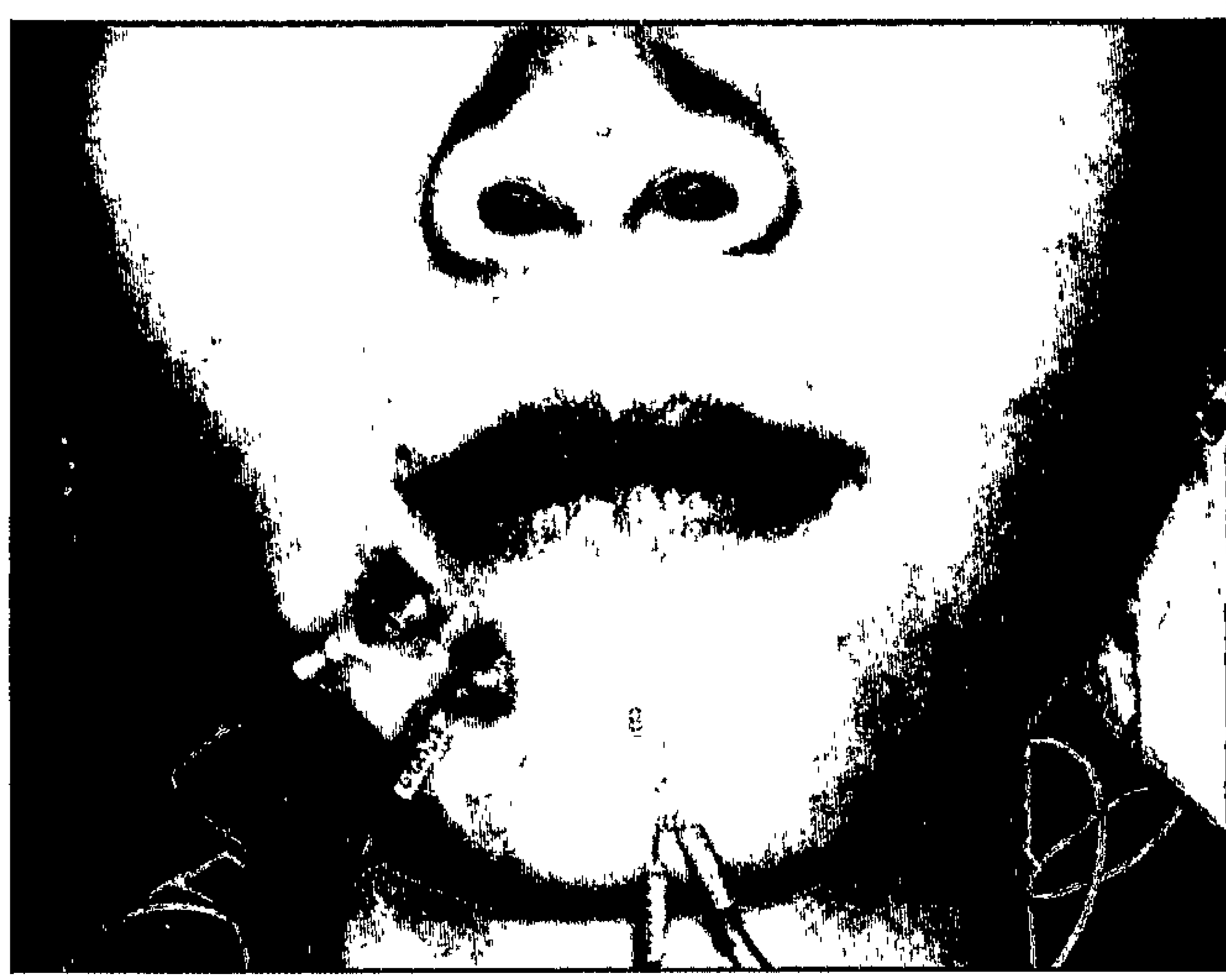
A

B



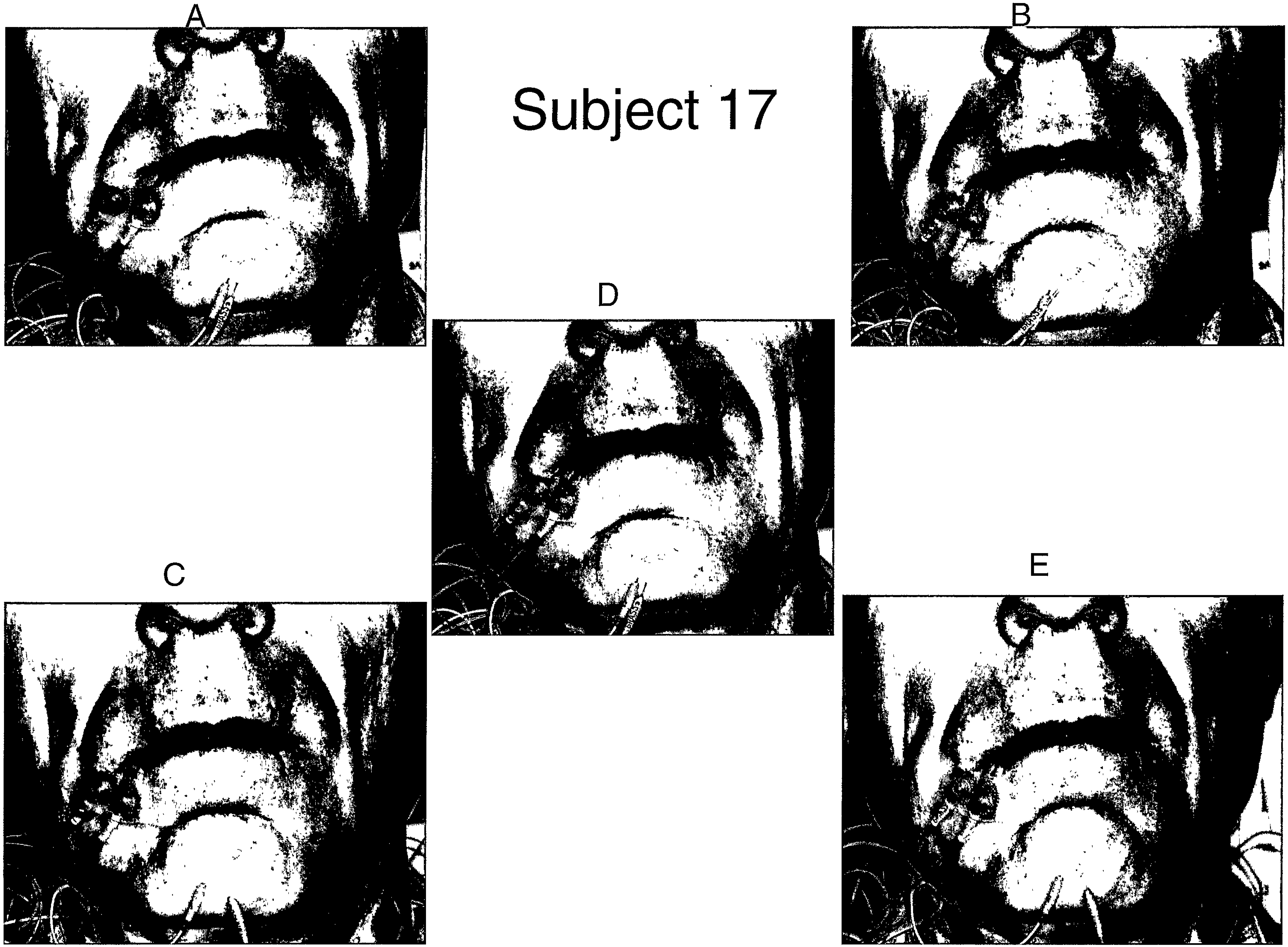
D

C



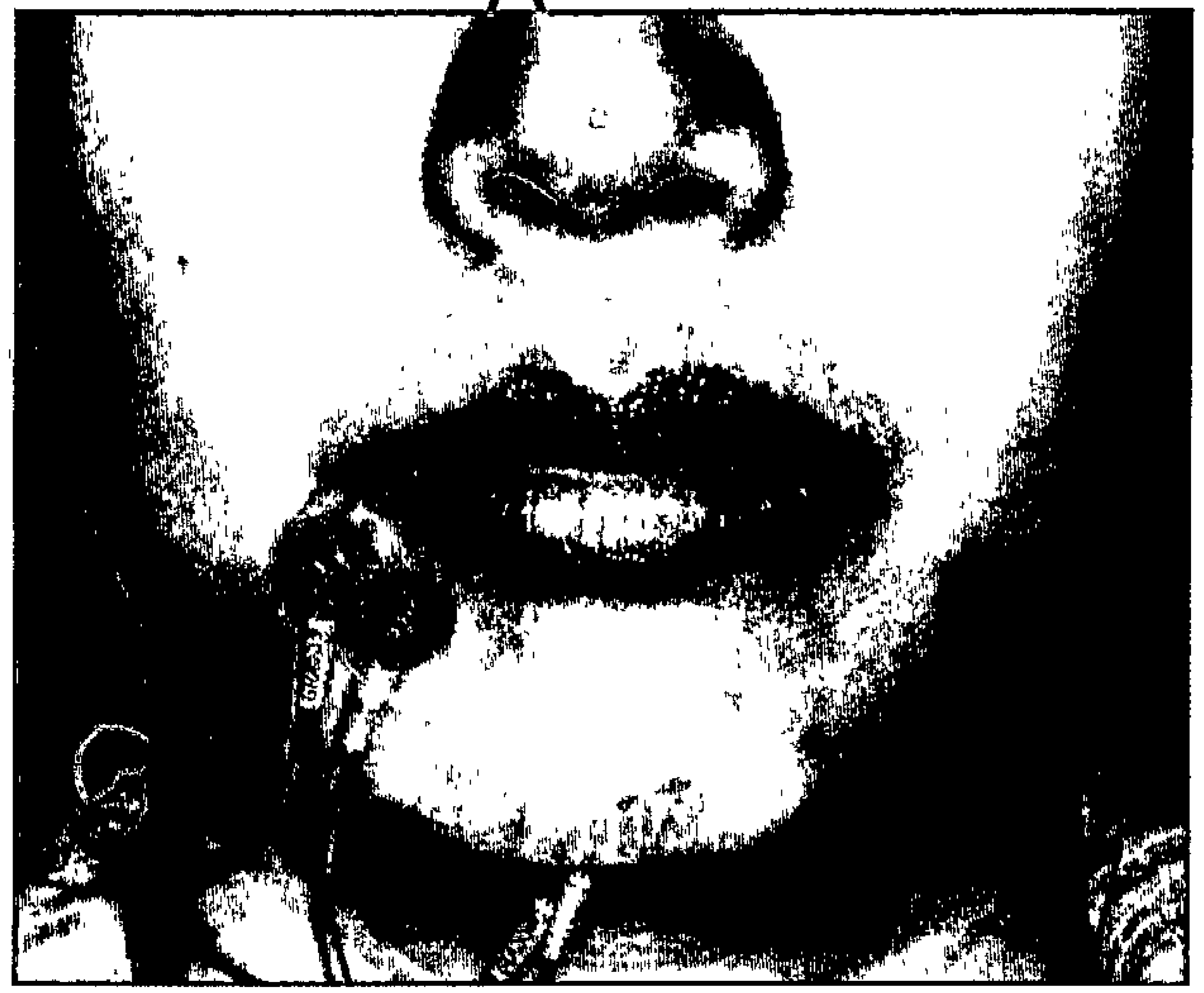
E

Subject 17

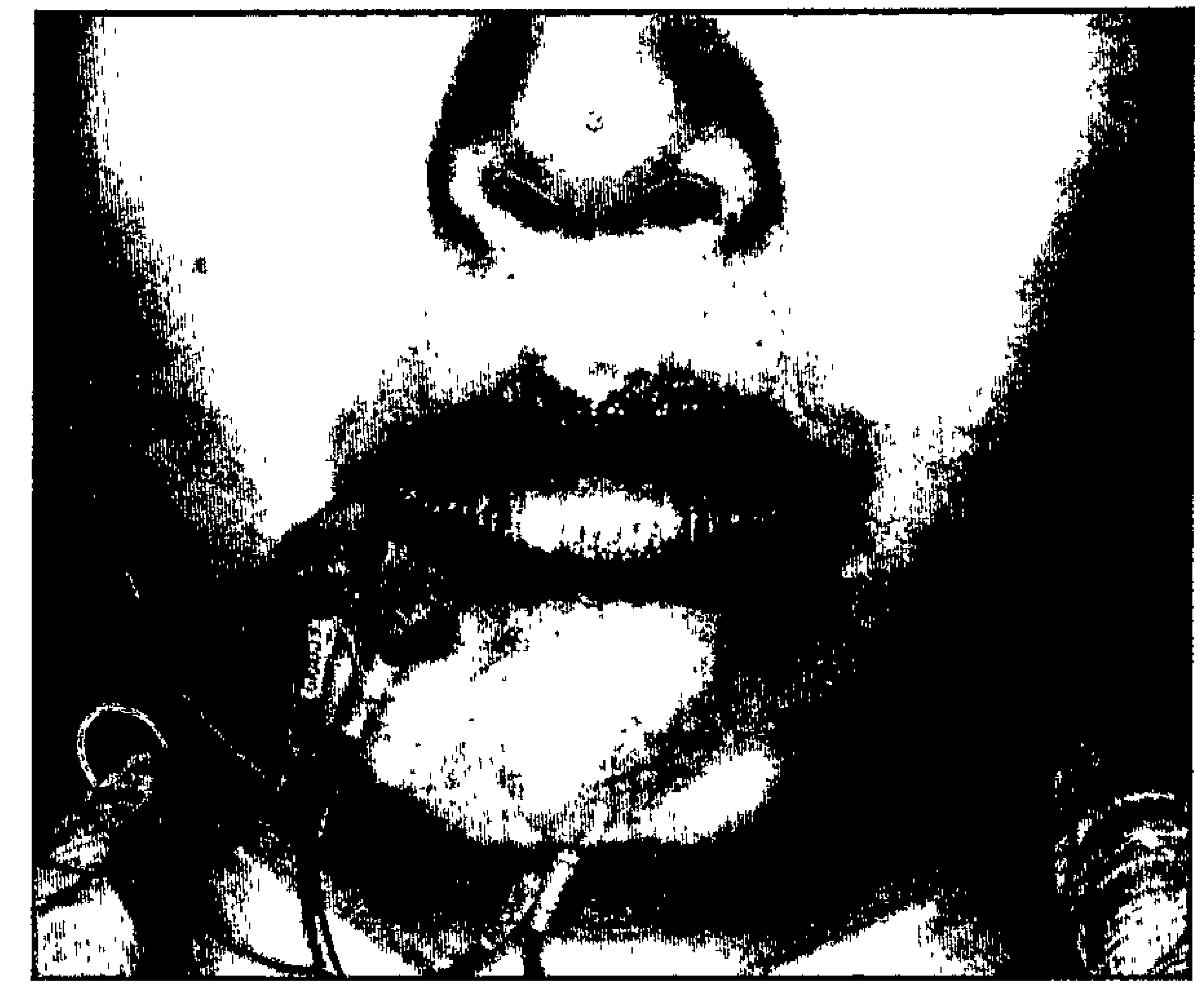


Subject 18

A

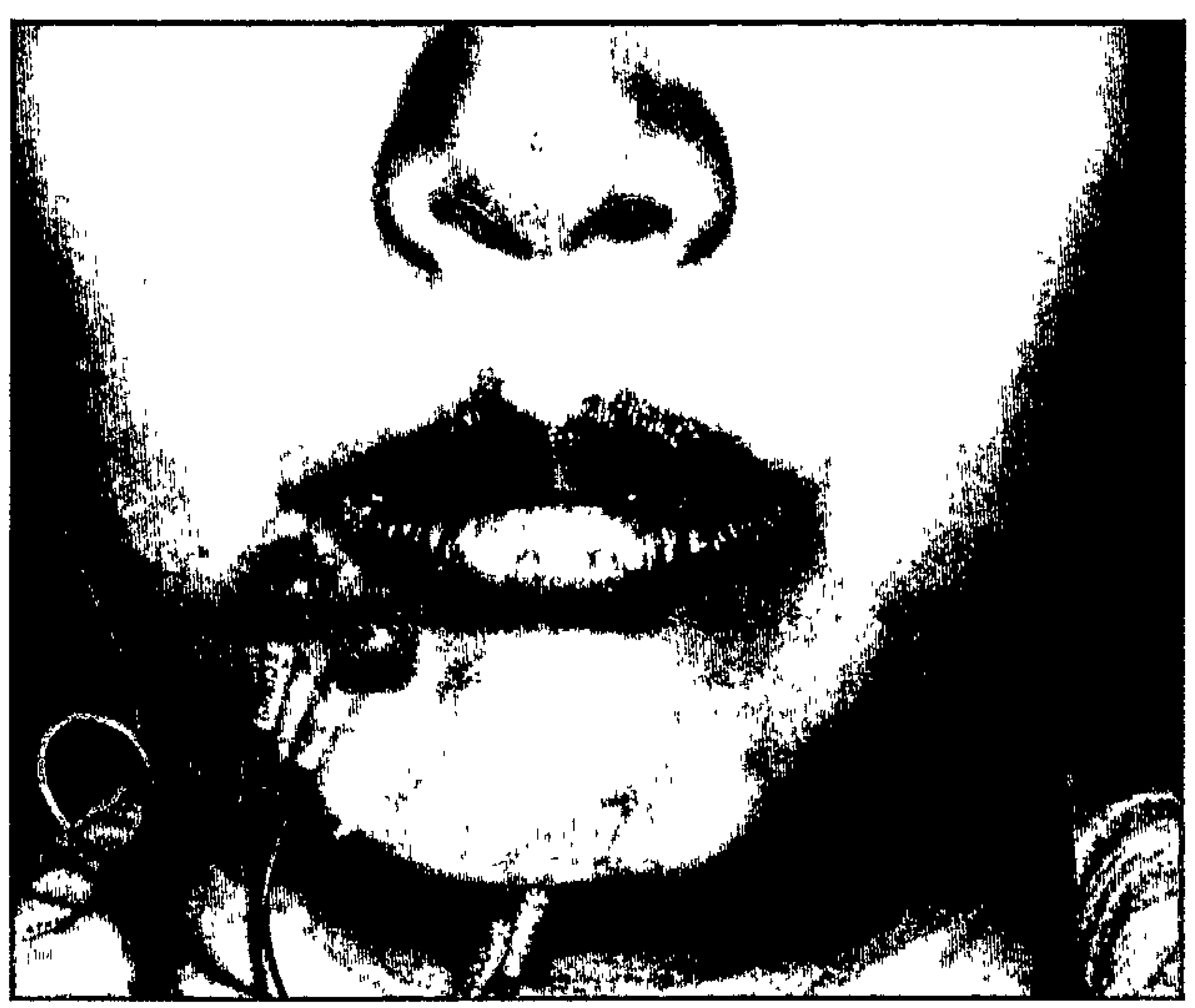


B



D

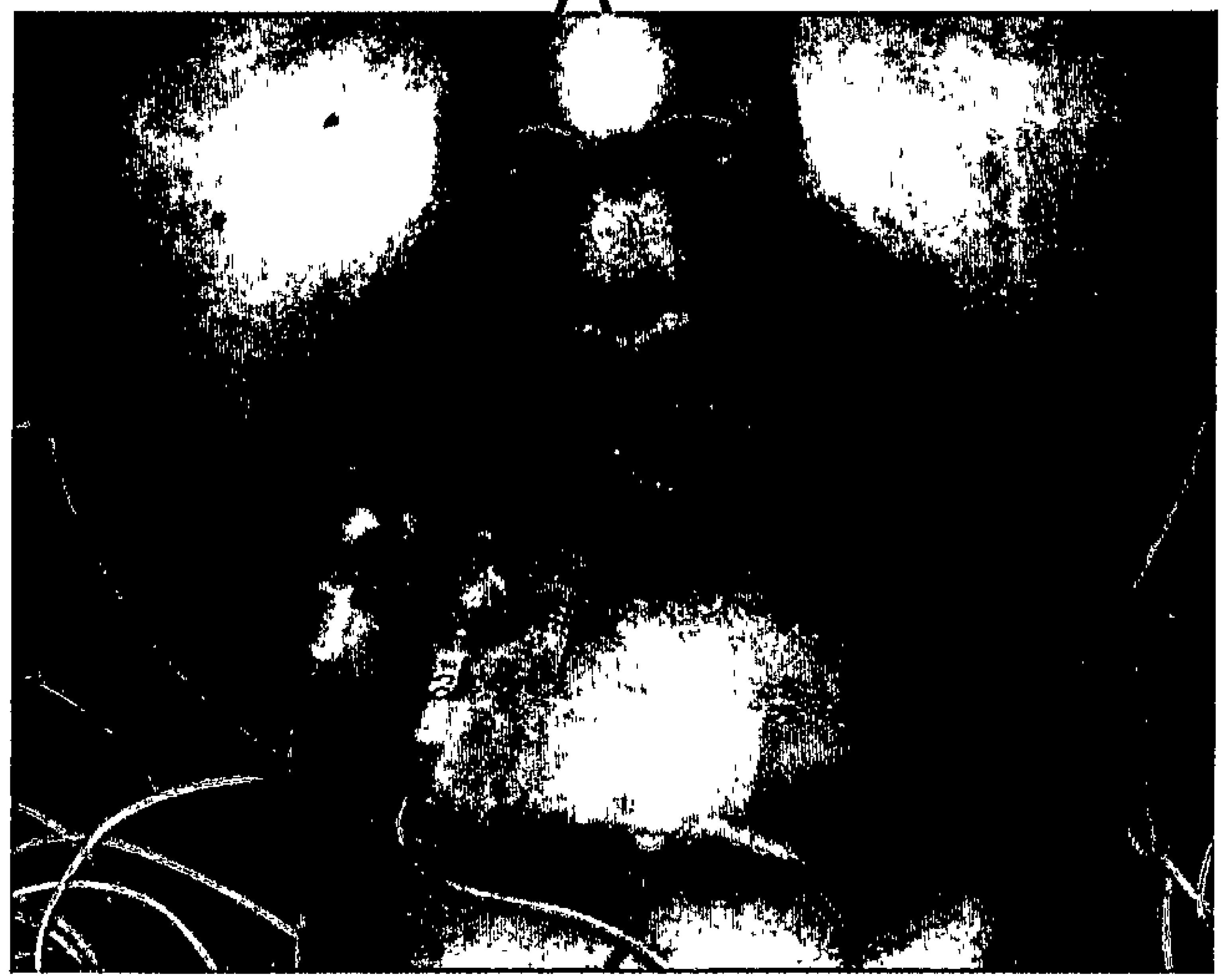
C



E

Subject 19

A



B

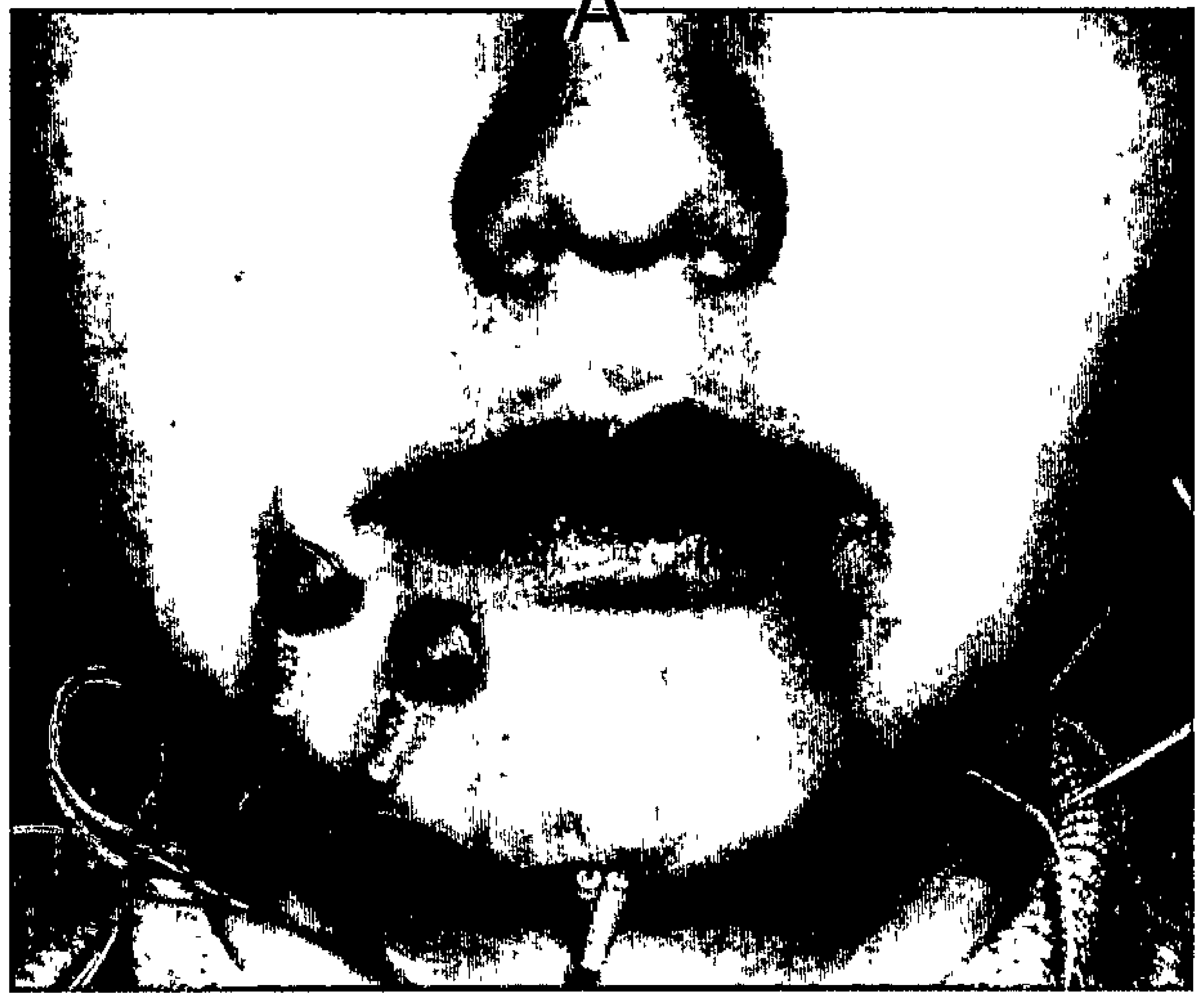
D

C

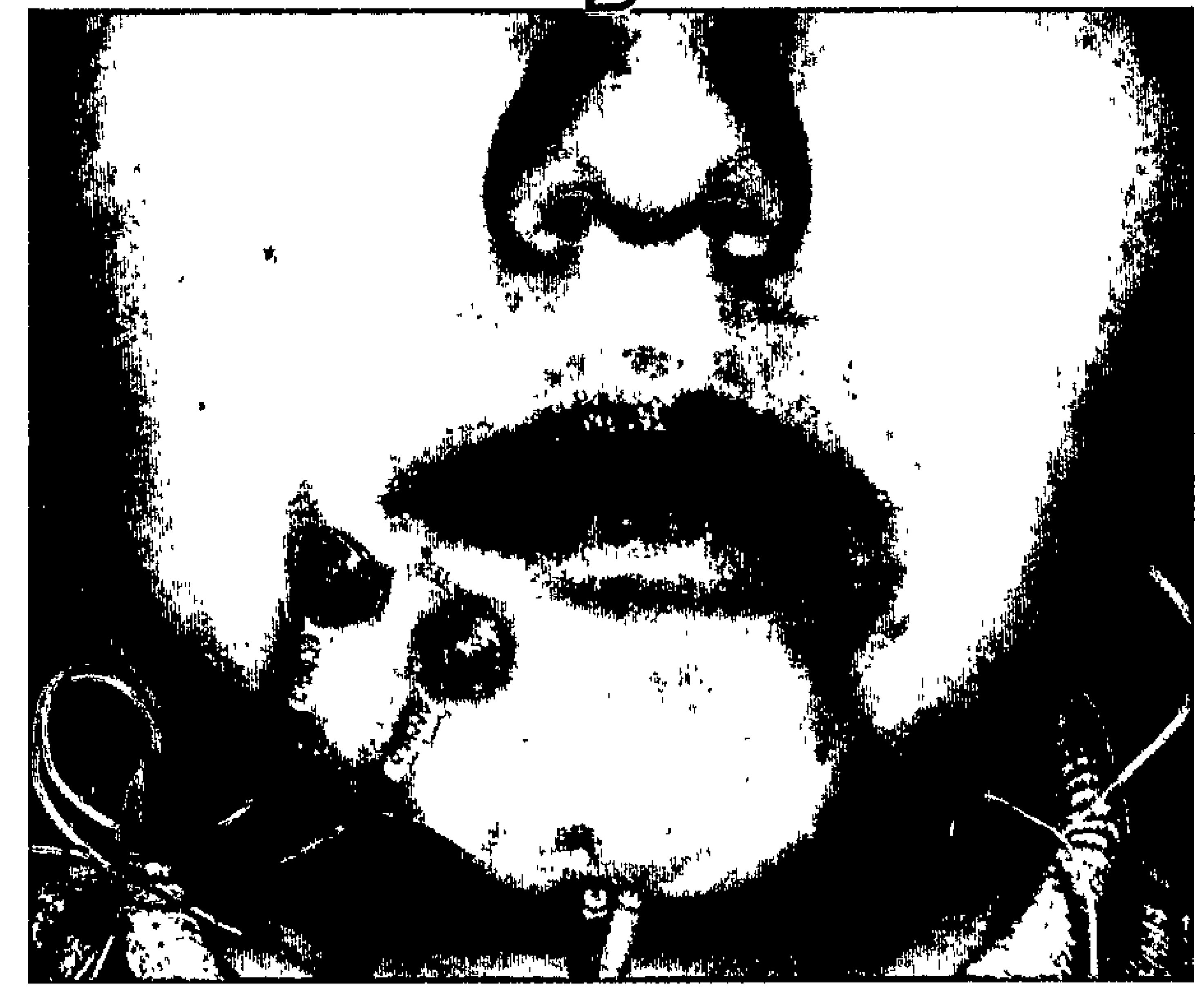
E

Subject 20

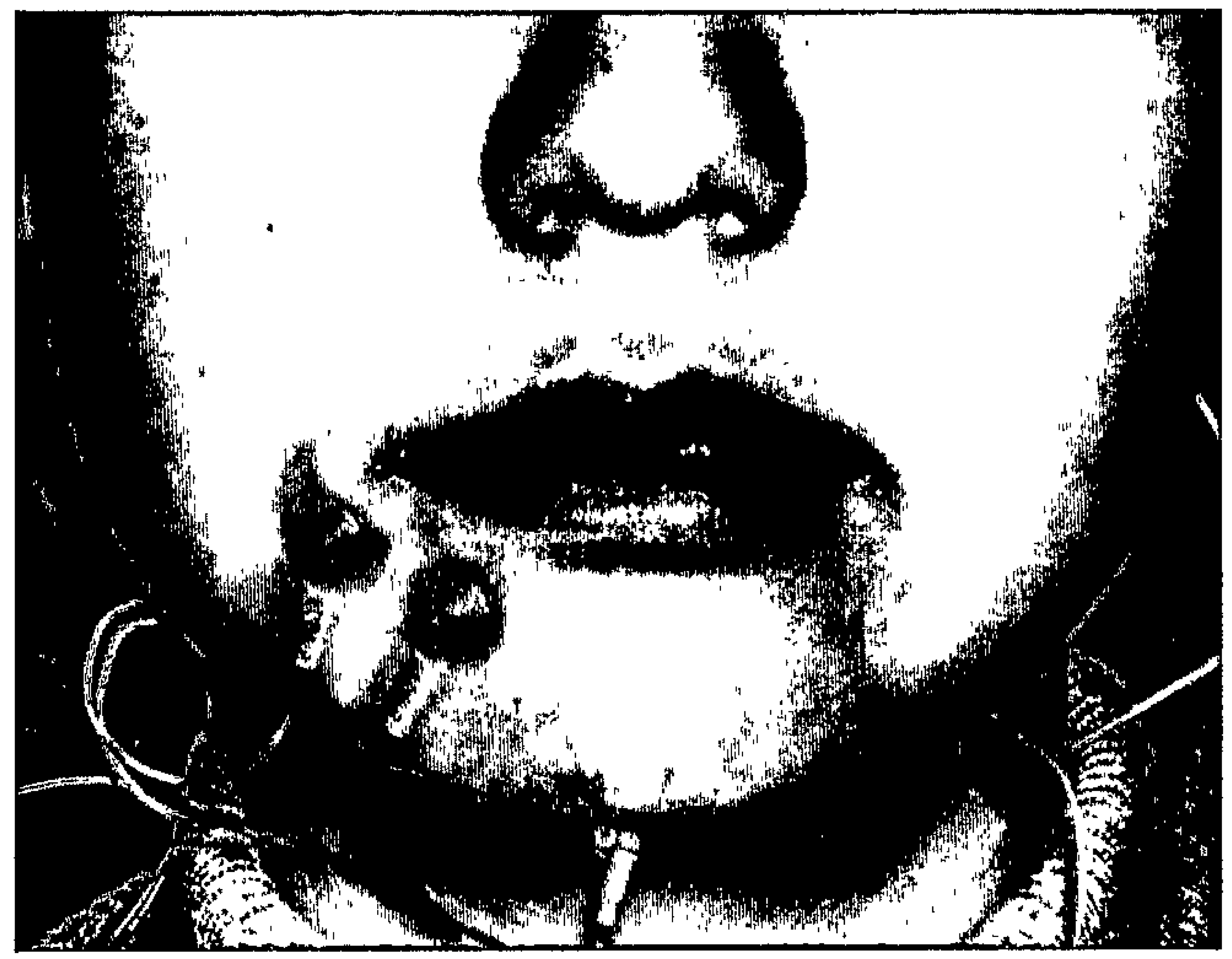
A



B



D



C

E

Five clinical photos (A~E) will be presented for each subject.

They consist of

- postural position without the splint
    - Each subject was asked to lick the lips, say "M, M, M", and lightly touch the lips, not the teeth, to establish the postural position. At the same time, tension in the lower facial third was observed.
- postural position with the splint (thickness of the splint is equivalent to the freeway space)
- postural position increased by 2mm on the splint
- postural position increased by 4mm on the splint
- postural position increased by 6mm on the splint

Rating procedures

- carefully observe the visual changes of the lower facial third amongst the photos
- Categorise the photos according to the classification below.

Subject	PP without the splint	PP with the splint	PP +2mm	PP +4mm	PP +6mm
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					