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Gnathodynamic analyses of function of the masticatory system using several tests of oral-motor function were examined in a sample of controls, and two groups of patients treated for fractures of the mandibular condyle. Patients were treated with either open reduction and internal fixation of their fracture or with closed reduction. Among patients treated non-surgically, deviation of the mandible towards the side of fracture was noted during opening of the mouth. Among those patients treated surgically, deviation of the mandible away from the side of fracture was noted. These results indicate that parameters of masticatory function, with a few exceptions, do not differ in patients treated with or without surgery for fractures of the mandibular condyle.

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Edward Elliott
PI Signature

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INTRODUCTION

The topic of condylar injury in adults has generated more discussion and controversy than any other in the field of maxillofacial trauma. It is an extremely important subject because such injuries are common; fractures of the condyle account for between 25% and 35% of all mandibular fractures in reported series.[23,75,79,92] Further, complications of trauma to the temporomandibular joint (TMJ) are far-reaching in their effects and not always immediately apparent. Disturbance of occlusal function, deviation of the mandible, internal derangements of the TMJ, and ankylosis of the joint with resultant inability to move the jaw are all sequelae of this injury. These problems are discussed below after a brief discussion of how condylar fractures are treated, and the biomechanics of jaw function following fracture of the condyle.

Treatment of Condylar Fractures

Unlike the non-surgical approach to condylar fractures in *children*, for which there is a great consensus of opinion, the treatment of condylar fractures in *adults* is still a highly debated theme. The broad range of treatment advocated for these individuals is best demonstrated in the statement by Malkin, Kresberg and Mandel:[63] "Concerning the treatment of condylar fractures, it seems that the battle will rage forever between the extremists who urge nonoperative treatment in practically every case and the other extremists who advocate open reduction in almost every case." The dichotomy between those surgeons who favor non-surgical and those who favor surgical treatment of adult condylar fractures is largely the result of two main factors. First, non-surgical treatment gives satisfactory results in the majority of cases. Second, there are no large series of patients reported in the literature who have been followed after surgical treatment since management of condylar fractures has historically been with non-surgical means. A review of the findings and associated problems with each of these methods of treatment highlights our lack of knowledge in this area.

Non-Surgical Treatment. Although non-surgical treatment is the most common method by which fractures of the mandibular condyle are treated, there is no unanimity of opinion regarding the most appropriate means by which this is accomplished. The most commonly-used method of non-surgical management involves a period of maxillomandibular fixation (MMF) followed by occlusal "guidance". Variables in this treatment are the duration of MMF and the method of occlusal guidance. While these may seem to be of little significance, they belie theories which may or may not have any underlying value.

The duration of MMF varies considerably from those who advocate "until the fracture heals", usually 6 weeks in adults,[15,26,27,43,81,109] to those who advocate a few to several days to overcome the discomfort from the traumatic edema in the muscles and/or TMJ.[3,5,41,50,78,107] Those individuals who believe that MMF should be continued until the fragments unite accept a non-reduced position following the injury. Further, they feel movement prior to healing will result in a fibrous union of the fragments. Those who advocate little or no MMF also believe that the position of the fragments is irrelevant, but that healing of the fragments will occur even in the face of active jaw movements. Their reason for mobilizing the jaw early is to "train" the muscles. In both circumstances, the formation of a "new" articulation, even if a pseudoarthrosis, is the goal of management.

The mode of occlusal "guidance" or physiotherapy also varies among surgeons. Most commonly, orthodontic elastics are used to apply force between the upper and lower dentition to "guide" the mandible into the proper relationship with the maxilla. These are usually continued until the patient can repeatedly close the mandible into the proper interocclusal relationship with the maxilla. However, the actual mechanism by which occlusal "guidance" maintains this objective is not clear. It may be a training of the musculature, i.e., establishing a new motor habit following loss of one or both temporomandibular (TM) articulations.

Further, it has been demonstrated that adaptations such as intrusion of the molars and extrusion of the incisors occur following condylar fracture, especially when interocclusal elastics are used (see below).

Surgical Treatment. Over the years, several authors have advocated surgical treatment for select condylar fractures. Their reasons are intuitively logical, arguing that since reduction and immobilization of the fracture is the goal in the treatment of every other skeletal fracture, the mandibular condyle should be no exception. These authors feel that the reason surgical treatment of condylar fractures is not practiced more commonly is because of the difficult access that surgery of the mandibular condyle presents, with the inherent anatomical hazards (i.e. VII nerve). However, most of these same authors reserve surgical treatment to condylar fractures which are displaced or dislocated, where a loss of vertical ramus support results.[12,15,18,33,47,48,51,59,62,67,68,72,80-83,95,96,101,102]

The goal of surgical treatment is to reduce the fracture, i.e. re-align the fragments to prevent the loss of vertical dimension occurring with fracture and dislocation. Another goal is prevention of postsurgical displacement of the fractured condyle by applying fixation devices (i.e. bone plates). Following surgical intervention, depending upon the rigidity of the fixation device(s), periods of MMF may be instituted and postsurgical physiotherapy with interocclusal elastics frequently used.

Biomechanics of Condylar Support

Current theoretical analysis and experimental measurements in animals indicate that forces normally are transmitted through the condylar processes during mastication and isometric biting.[4,11,32,36,38,40] Earlier studies suggesting that no forces are transmitted through the temporomandibular joint have been shown to contain serious faults.[35,38] These condylar forces serve in part to support and maintain vertical position of the masticatory apparatus during mastication and biting. The exact magnitude of these forces are currently unknown, but current theory suggests that during incisor biting both condyles will normally be loaded equally and that during unilateral biting and chewing the working side (ipsilateral) condyle will normally be less heavily loaded than the balancing side (contralateral) condyle.

The masticatory system is inherently highly adaptable and these normal patterns of loading could be modified by altering muscle activity patterns during biting and chewing.[30,98] Theoretically, loads on the working side condyle could be reduced or eliminated, although there is no evidence that this occurs in normal individuals.[98] However, it seems likely that individuals with damaged temporomandibular joints will adapt their muscle activity patterns in ways that will reduce load on the damaged joints. In addition, neuromuscular adaptation should be required to generate normal occlusal forces following damage to the temporomandibular joints. One purpose of this study is to investigate how muscle activity patterns adapt to altered biomechanical conditions following damage to the temporomandibular joints with and without surgical intervention.

Compensatory Mechanisms Occurring After Condylar Fracture

Condylar fractures with displacement or dislocation result in a loss of skeletal support to the mandible, i.e., the effective length of the mandible on the side of fracture is reduced. This is why bilateral fractures tend to produce anterior open-bites and unilateral fractures produce deviation toward the fractured side. Those surgeons who advocate open reduction of displaced or dislocated condylar fractures feel that re-establishment of mandibular length and ramus height obviates the need for most of the compensatory mechanisms discussed below. While this seems intuitively obvious and *may* be true, there are no studies of functional adaptation to surgical treatment of condylar fractures.

With *non-surgical* treatment, adaptations occur which help compensate for this loss of vertical ramus support and allow, in most instances and with physiotherapy, the maintenance of a proper occlusal relationship. These can be broken down into adaptations within the neuromusculature, the skeletal tissues, and the dentition.

Neuromuscular Adaptations. Following condylar fracture, neuromuscular adaptations may occur which allow establishment of a proper occlusal relationship. However, the nature and extent of these adaptations are very poorly understood. Biomechanical theory[10,17,18,20,30,37-39,85,86,99] predicts that loss of support from one condyle should produce several neuromuscular adaptations to shift forces away from the damaged or missing joint: 1) Chewing might be confined to the same side as the fracture since as the working side condyle it would theoretically be less loaded than the balancing side joint. 2) Muscles on the non-fracture side would be theoretically expected to increase their activity levels relative to those on the fracture side in order to further reduce the load on the damaged condyle. However, there is a functional cost to these first two adaptations. Theoretically, reduction of the load on one condyle (without reducing occlusal force) must be compensated by increased load on the opposite condyle. Therefore, it is possible that decreased loading of the non-functional condyle might, over the long term, produce degenerative changes in the healthy condyle. 3) Reduction of occlusal force, particularly during incisor bites, would reduce the magnitude of forces on both condyles.[37,38] 4) Alterations of muscle activity, for example a relative increase in posterior temporalis activity, could theoretically shift the total muscle force closer to the position of the bite. This adaptation could reduce or, for molar bites, even eliminate loads on both condyles.[73,74,84,88,93,103,104] However, this adaptation would also reduce occlusal force. It is therefore probable that if this mechanism is used, it is only a short-term adaptation, used until a new TM articulation has been re-established by the adaptations discussed below. Currently there is little experimental evidence to indicate how the neuromuscular system adapts to loss of condylar support in the ways predicted by biomechanical theory. No studies to date have looked for reduced occlusal force or altered muscle activity patterns in subjects in which condylar displacement is not reduced. Although unilateral chewing following condylar fracture is well known[26,27,71,91] it is not clear whether this results from reduced ability to translate or an attempt by the masticatory apparatus to reduce joint forces. If neuromuscular adaptations occur following condylar fractures which allow maintenance of a normal occlusal relationship, they have not been identified or quantified.

Skeletal Adaptations. With displacement, dislocation or even condylectomy, a complex series of changes occur within the TMJ which have the potential of producing a new mandibular condyle. Lindahl and Hollender[55] called this process condylar "restitution", and it has been demonstrated by dozens of investigators in both animals[9,34,45,57,66,77,87,100] and humans.[7,28,55,58] This is the same response that orthopedic functional appliances rely upon to treat skeletodental malocclusions.[64] Of note, however, is that this response is maturation-dependent. Skeletally *im*mature individuals regenerate condyles very rapidly following fracture dislocation. On the other hand, skeletally mature individuals (adults) have a more limited ability, and instead of "restitution" of a new condyle, a "functional" remodelling is the rule.[55] The remodelled condyle functions as a TM articulation allowing hinging motion but does not appear "normal" in most instances. Further, re-establishment of the lost vertical ramus height does not occur in these cases. Instead, the remodelled condyle articulates anteromedially against the articular eminence and/or skull base. The mandibular fossa slowly fills in with osseous tissue and becomes shallow. Thus, the skeletal adaptations which occur following fracture in the adult consist less of condylar regeneration, which occurs in the young and is the most advantageous skeletal adaptation possible, but of remodelling and the formation of a new articulation along the eminence, with some permanent loss of vertical dimension and mandibular length.[29]

Dental Adaptations. With loss of posterior vertical dimension of the ramus from fracture, the only manner in which a normal occlusal relationship can be maintained is if the musculature brings the mandible into occlusion irrespective of a TM articulation, or if the teeth have adapted by extrusion/intrusion. For instance, after a bilateral condylar fracture in an adult, loss of posterior vertical dimension results in an anterior open-bite until "training of the musculature" by interocclusal elastics allows re-establishment of the normal occlusal relationship. Whether the muscles are actually being "trained" has not been demonstrated, although we know from clinical experience that patients can usually obtain a normal occlusal relationship within a few days following institution of interocclusal elastics when they are used. Later, however, it seems probable that a new TM articulation is re-established by the skeletal adaptations noted above. Since a loss of posterior vertical dimension is a permanent finding in adults, the only way a normal occlusal relationship can then exist is for the anterior teeth to extrude and the posterior teeth to intrude. Götz *et al.*[29] found that this response occurs routinely when non-surgical treatment of condylar fractures is instituted. The mandibular plane was shown to become more steep in every case, reflecting the shortening of the ramus from condylar fracture. Thus, the interocclusal "training" elastics may initially help develop a neuromuscular adaptation, but in time, a new articulation is established by shortening of the ramus until the condylar stump either heals to the displaced condylar head or re-establishes a new articulation somewhere along the cranial base. For the occlusion to be maintained, the dentition must adapt, and the elastic therapy probably facilitates this response.

Masticatory Function Following Condylar Fractures

A potential problem when non-surgical means are used to achieve a correct occlusal relationship in the face of loss of posterior vertical dimension resulting from the fracture is an over-stressing of the contralateral, uninjured TMJ. Several investigators have noted that patients who have pain and/or dysfunction of one TMJ preferentially chew on that side, i.e. unilaterally masticate.[26,27,71,91] Since the mandibular condyle frequently loses it's ability to translate following fracture, patients tend to chew on this side, allowing translation on the opposite, uninjured joint for the development of masticatory force. Hylander[38] has experimentally demonstrated that the contralateral (balancing) joint undergoes more compression across its surface during the power stroke of mastication than does the side of the bolus (working side). It is probable that unilaterally masticating on the side of injury helps to "protect" the injured joint by subjecting it to less compressive force during mastication. It is not surprising that patients who sustain unilateral condylar fracture frequently develop pain and dysfunction in the opposite joint up to years later.[1,26,27,53,54,59,76,89,90]

Further, it is becoming increasingly apparent that injuries to the TMJ result in late pain and dysfunction in the injured joint.[18,21,28,52,65] These investigators feel that injuries in the TMJ hasten the development of degenerative joint disease and may produce internal derangements. Curphey[18] states that *all* cases of fracture dislocation will result in painful symptoms. Because of this, he feels it essential to surgically return the condyle to the fossa.

Despite the common occurrence of condylar fractures, there is little scientific data to suggest that any of the instituted treatments are effective in normalizing function of the masticatory apparatus. "Success" of treatment has never been defined. Most investigators feel that successful treatment of condylar fractures includes the ability to obtain a pre-traumatic occlusal relationship and good range of mandibular motion (usually >40 mm).[2,3,5,6,14,16,49,60-63] However, the percentage of "successfully-treated" cases reported in large series using these *minimal* criteria is only somewhere around 85%. Of interest is the finding that all *large* studies of patients treated for condylar fractures have been those where treatment was non-surgical.

Conceivably, surgical treatment may improve results since it has been demonstrated that closed-treatment of displaced articular fractures in other joints is complicated by both early dysfunctions and late arthritic changes which may occur 10 to 50 years later.[22] Unfortunately, we do not know if surgical treatment of condylar fractures may fare any better than non-surgical treatment since reports are not available in the literature.

There have been a few studies which have tried to more thoroughly evaluate oral-motor function and masticatory/TMJ dysfunction in patients treated non-surgically for condylar fractures. Most of these have used maximal mouth opening, mandibular deviation, TMJ crepitus, TMJ radiographs and subjective reports by the patients to determine treatment outcomes. Generally, the results are not encouraging.

Summarizing the literature with respect to function/dysfunction following non-surgical treatment of condylar fracture, the following conclusions can be reached:

1) Signs and symptoms of dysfunction occur in 12%[52] to 85%[44] of cases depending upon the study and the testing modalities used for assessment.
2) Dysfunction is much more common when fractures are sustained in skeletally mature individuals (adults) than when sustained in the young.[19,28,56]
3) Signs and symptoms of dysfunction are more frequently when there is no contact between the condylar head and the fossa following fracture (i.e. displaced and dislocated fractures).[15,19,26-28,42,52,53,56,59,89,90,95,96]
4) TMJ dysfunction occurs in both the injured joint and in the contralateral, uninjured joint.[26,27,44,52,53,56,59,89,90]
5) Displaced/dislocated condylar fractures result in an increased distance between the intercuspal and retruded condylar positions, the significance of which is unknown.[19,42,56,69]
6) Most studies of mandibular function to date have not used methodology nor techniques which are sensitive indicators of masticatory function.
7) Details of neuromuscular adaptation remain unresolved.
8) The functional capabilities of patients following *surgical* treatment of condylar injuries is unknown.

The purpose of this investigation was to expand our knowledge concerning oral-motor function following surgical and non-surgical treatment of fractures of the mandibular condyle in adults. Six tests of oral-motor function were examined in all subjects in order to develop a more complete picture of function in patients who sustain fractures of the mandibular condyle.

Two *general* hypotheses were tested:

1) Patients treated with open reduction and internal fixation of condylar fractures will have less impaired oral-motor function than those treated non-surgically.
2) Among patients treated non-surgically, oral-motor function will be more impaired in those with significant condylar displacement (or dislocation) than those with minimal displacement or no displacement.

Six *specific* questions were addressed in this research to test the above hypotheses. The questions concern parameters of oral-motor function which were tested in all patients:

1) Are resting levels of adductor muscle activity elevated? Resting levels are used as a baseline for comparison with muscle activity during function. Activity levels elevated beyond those found in controls may indicate pain or other aspects of muscle dysfunction.

2) Are there reductions in the maximum range of motion, and if so, are the limitations due to pain, muscle limitations, or restrictions within the soft tissues?
3) Are limitations in range of motion or changes in muscle activity patterns present during mastication? Significant deviation from patterns seen in controls would indicate that limiting factors are affecting masticatory function.
4) Are there reductions in maximal occlusal force generation or reduction of muscle efficiency at submaximal occlusal forces?
5) Are changes in muscle activity patterns reflecting attempts to protect the affected joint from loading? Differences in activity patterns from those of controls may indicate redistribution of the two joint forces.
6) Are muscle activity patterns altered by occlusal guidance with post-fracture interarch elastics to compensate for loss of condylar support.

Evaluating patients with condylar fracture who were treated non-surgically provide insight into the biology of adaptations which occur in the masticatory system to this traumatic insult. Comparison of the functional and anatomical results of the two most common forms of treatment for condylar fracture provided information about the efficacy of our therapies.

BODY

Methods

1. Patient Selection

This investigation was a non-randomized clinical trial of two treatments of condylar fracture. Patients admitted to the Parkland Memorial Hospital with fractures of the mandibular condyle were asked to participate in this study. The proposed treatments and analytical procedures were explained. Patients who met the inclusion criteria (below) and who consented to participate in the randomized portion of the study were asked to sign an IRB-approved voluntary consent form.

Criteria for inclusion of a subject into this investigation were: 1) age--18 years or greater; 2) isolated injuries of the mandible where one or both condyles have been fractured (high intracapsular fractures were excluded--these are impossible to treat with open reduction and fixation); 3) medical condition--American Society of Anesthesia (ASA) Classification I or II (no major medical problems); 4) state of dentition--partial edentulism permitted as long as bicuspid occlusion present and bilaterally symmetrical; 5) no pretraumatic history of TMJ/MPD (myofascial pain & dysfunction); 6) no gross pre-traumatic skeletal malrelationship of the jaws and associated malocclusion; 7) patient consented to participate. We preferred to use skeletally mature individuals since the controversy over treatment regimens surrounds these patients. Further, it is in these patients that most reports of post-traumatic masticatory dysfunction are found. Bilaterally symmetrical occlusion is important since if a unilateral pattern of mastication is noted post-fracture, an occlusal cause can be eliminated. Other fractures of the mandible were permitted in both treatment groups. However, for subjects in the *surgical* group, inclusion depended upon the rigid internal stabilization of the other fractures with bone plates and screws, permitting immediate, active mandibular function (no MMF). The patients' systemic health must have permitted general anesthesia and surgery. A detailed history of the patient to establish eligibility was obtained using the *Patient History* form (see Appendix).

2. Treatment Groups

The risks and benefits of each treatment as we perceived them were discussed with patients who sustained condylar fractures by the principal investigator. An attempt was made to standardize the discussions. Patients select one of two treatment groups: 1) Surgery, and 2) Non-surgery.

Surgery Group. Patients in the surgery group had arch-bars placed on the maxillary and mandibular dentition. All mobile fractures of the mandible were rigidly stabilized using internal bone plate and screw fixation. This allowed immediate use of the mandible following surgery. The surgical approach varied considerably depending upon the anatomical location of the fracture(s).

Non-surgery Group. Patients in the non-surgical group underwent application of arch-bars and 6 weeks of MMF. Other fractures of the mandible which required open reduction to reposition and/or control fragments had open reduction of these other fractures. However, the fractured mandibular condyle did not undergo surgical repositioning and/or stabilization. Six weeks of MMF was adequate time for other fractures of the mandible to become stable.

Post-fracture Physiotherapy. Patients in both groups were instructed in the same physiotherapy protocol. However, patients in the *surgery* group were able to have these exercises instituted immediately after surgery whereas those in the non-surgery group began exercises at 6 weeks post-surgery, when MMF was released. The protocol was that routinely used in our hospital at the time and consisted of the following:

1) Occlusal Guidance--Any patient unable to easily repeat their normal occlusal

relationship were placed in elastics (rubber bands). This usually consisted of one or two elastics between the maxillary and mandibular arch-bars placed bilaterally in the cuspid/bicuspid region. Frequently, they were positioned such that they imparted an anterior vector to the mandible. The elastics assisted in obtaining the normal occlusal relationship. They were *not* meant to provide MMF--mandibular mobility was desired. Therefore the lightest forces which helped restore the patient's occlusal relationship were used. The elastics were worn 24 hours a day for six days. The patient was allowed to remove them to eat and brush the teeth, but they were replaced immediately.

The elastics were withdrawn 24 hours prior to being seen for the appointment one week following surgery in the *surgery* group, or one week following release of MMF in the *non-surgery* group. If the patient could obtain a normal occlusal relationship at the one week visit, the elastics were omitted. If the occlusion was still difficult to obtain, the elastics were maintained. The patient was weaned off the elastics by switching from 24-hour wear to wearing them only at night. This may have taken several weeks of wearing, especially in the non-surgery group. The arch-bars were maintained at least two weeks beyond the time when elastics were no longer necessary.

2) Functional Exercises. Four exercises were prescribed for the patient--maximal mouth opening, right and left lateral excursions, and protrusive excursions. The post-fracture functional exercises were goal-oriented. Each week, the patient was given a new goal which was based upon the previous recording of their progress. For instance, on release of MMF in the *non-surgery* group or the day following surgery in the *surgery* group, a patient may have opened 15-20mm between the incisors and had very limited lateral and protrusive excursions. An increase in 5mm of interincisal dimension was added each week to that value until a minimum of 40mm was achieved. If the patient had difficulty achieving their goal for interincisal opening, the use of wooden tongue-blades wedged between the terminal molars was instituted by the patient several times during the day until the goal was met. They were encouraged to try and maintain their mandible in the midline when they opened or protruded the mandible, however, this goal was not routinely achieved in unilateral fractures which were displaced/dislocated. For lateral and protrusive excursions, an additional 2mm per week was added until lateral excursions were greater than 10mm and protrusive greater than 12mm. Patients were not released from active treatment until these goals were met.

3. Methods of Data Acquisition

Clinical assessments of function took place at least four times during the study. Both groups underwent complete recording sessions (described below) at 8, 12, 24 and 48 weeks following institution of treatment. Radiographs, while obtained prior to and immediately after surgery, were also be obtained at these times. Attempts were made to obtain 2- and 3-year follow-up visits in all patients in addition to the above times.

A. Radiographic Analysis

Panoramic Radiography. Panoramic radiographs were obtained on all patients prior to treatment, immediately after surgery, and at each evaluation period using a single radiographic machine. The purpose of this film was for assessment of the dentitional state of the individual, as a scout for other fractures, etc. No quantification or assessment were performed from these films.

Cephalometric Radiography. Posteroanterior (PA) cephalometric radiographs were obtained for each subject immediately after surgery and at each evaluation period using a single radiographic machine (Quint Sectograph) with a standardized source-object distance (60"). Each radiograph was traced onto acetate and digitized using a cephalometric model which includes 24 dental and skeletal landmarks. A computer program (Ceph-Master, Trilobyte Inc., Northville, MI) calculated linear, angular, and ratio measurements among the 24 points. Analysis of this information allowed assessment of morphological differences among the patients and determined if skeletal changes occurred following treatment.

Linear Tomography. Each subject received a sagittal linear tomographic examination of both TMJs prior to treatment, immediately after surgery, and at each evaluation period. This was performed using a Quint Sectograph which allowed standardized films to be repeated due the incorporation of a head positioner (cephalostat). The sagittal images were taken perpendicular in the sagittal plane using the cephalostat with the patient positioned as if a lateral cephalogram were being taken. No "correction" to the mediolateral axis of the mandibular condyle was performed since the axis of the condyles are at different positions in each patient following fracture and during treatment. Sufficient 3mm cuts were obtained to completely image the condyle, from lateral to medial poles in the sagittal images and from anterior to posterior in the coronal images in the closed-mouth position. Mid-condylar sagittal cuts were also obtained in a maximum gape position of the mandible to evaluate condylar mobility.

The tomograms were traced onto acetate for three purposes. First, classification of the fracture according to Lindahl[54] was performed. This system classified condylar fractures by the following means: 1) Fracture level--condylar head, condylar neck, subcondylar. 2) Dislocation of the fragments at the level of the fracture in both coronal and sagittal planes for condylar neck and subcondylar fractures--The angulation which the condylar segment makes with the ramus in the coronal plane was calculated using a protractor. The presence and direction of overlapping of the condylar and ramal segments were quantified in millimeters, i.e. medial override; lateral override; angulation without override; fissure, etc. Similar measures were calculated in the sagittal views using a line drawn between the posterior border of the ramus and the long axis of the condylar fragment. Fractures were categorized into those with less than 20° of angulation, 21-45°, and >45°. 3) Position of the condylar head with respect to articular fossa)--no to slight displacement, moderate displacement, severe displacement (dislocation--condyle no longer in contact with fossa).

This information was tabulated to determine how similar the two treatment groups were prior to treatment. Second, sequential observations of morphological alteration were possible (qualitative) by superimposing tracings on stable cranial base structures. In this manner, it was possible to evaluate how condylar remodelling correlated with changes in subjective and functional parameters over time for both the injured and the non-fractured condyle. Third, assessment as to the magnitude of condylar translation from the closed- to open-mouth radiograph was quantified by direct measurements between the mid-condylar points in the closed-mouth and maximal gape tomograms (after superimposing on cranial base structures).

B. Clinical Analysis of Function

Subjective assessment of function. Questioning the patient at the follow-up appointments to determine the patient's assessment of function was performed using a standardized questionnaire (see Appendix). The subjective assessment of function consisted of five categories: 1) presence of pain, 2) presence of joint noise, 3) perceptible change in occlusion, 4) limitations in range of mandibular motion, and 5) limitations in diet. Patients were scored as being positive or negative for these criteria. This data were used to determine how patients' symptoms change over time, differed between patient groups, and correlated with objective measures of function.

Gnathodynamic assessment of function. A quantifiable assessment of function was obtained using simultaneous recordings of electromyography (EMG), three-dimensional movements of the mandible, and voluntary bite-force recordings. The methods of obtaining the functional data are described below:

1) Measurement of Mandibular Motion. In all experiments measuring mandibular motion the subject was seated upright and relaxed in a comfortable wooden chair with Frankfort horizontal parallel to the floor. A special magnet was attached to the gingiva at the base of the central incisors with a removable adhesive and a magnetic sensor array (Sirognathograph, Siemens Corp.) was placed on the head so that the jaw magnet was located at its center. The magnet's position, to the nearest 0.1 mm, was recorded around three orthogonal axes in real time and was monitored on a computer screen (IBM AT) following each functional test. The amount of motion was displayed either as motion in two planes (Sagittal and Frontal) or as deviation of three traces (Vertical, Lateral, and Anteroposterior), with time (Sweep Mode). In the display of motion in two planes, maximal and average numerical values for motion along the three axes were displayed automatically on the computer screen. In the sweep mode, muscle deviation in three directions and jaw muscle activity levels were recorded simultaneously during each motion. Portions of each tracing of jaw position was measured using a keyboard controlled cursor, and the values were correlated with the electromyographic information from the jaw muscles.

Two types of movement were recorded: 1) Voluntary Maximum Excursions and 2) Movement during mastication of a constant bolus.

1) For voluntary maximum excursions, the patient was asked to voluntarily move their mandible to its maximum open position, then with the teeth in contact, to produce the maximum left and right deviations and protrusion. Each movement was repeated five times and the following measurements were recorded to the nearest 0.1 mm: During opening, a) Maximum interincisal distance, b) Maximum vertical excursion, c) Maximum protrusion; and with the teeth in contact: d) Maximum left excursion, e) Maximum right excursion, f) Maximum protrusion. Comparison was made with voluntary ranges of motion in controls to indicate abnormal ranges of voluntary motion.

2) The patient was given a standardized constant bolus (Gummi-Bears, HARIBO, GMBH & Co., Bonn, West Germany) and asked to chew naturally for 10 cycles while jaw position and muscle activity patterns were recorded. The test was then repeated with a fresh bolus for an additional 10 cycles. Maximum and average excursion in the vertical, lateral, and anteroposterior directions were recorded and compared to the maximum voluntary ranges of motion, and excursions during mastication in controls.

2) Measurement of Muscle Activity. Electrode sites were scrubbed with alcohol and pairs of pregelled disposable silver/silver chloride electrodes (Electrotrace, Huntington Beach, CA) were placed over the superficial masseter, anterior temporalis, posterior temporalis, and suprahyoid muscles bilaterally. Signals from the eight muscles were amplified using a set of eight differential amplifiers (Bio-pak, Bio-Research Associates, Milwaukee,WI) with a band pass of 40-1000 Hz and were digitized in real time at a sampling rate of 1.2 KHz per channel using Bio-pak software. Digitized signals from all channels were monitored on the computer screen immediately following each test. Comparison of recording levels was adjusted using a common 0.5mV, 600 Hz calibration signal. Maximum voltage (in μV) and the integrated EMG values (in μVmsec) for each trace were also automatically displayed. Levels of muscle activity were recorded as average integrated EMG (IEMG) over a two second interval. Muscle activity was measured 1) during resting in centric occlusion, 2) during rest while biting on the bite force transducer (see below) at various tooth positions, 3) while producing various levels of occlusal force at various tooth positions, and 4) during mastication.

1) Baseline muscle activity levels were recorded for a one-second period while the subject was relaxed in centric occlusion, producing no mandibular motion or occlusal force. These baseline levels were examined for evidence of hyperactivity and to determine amounts of activity increase during function.

2) Second, muscle activity levels at each of the 9 tooth positions listed above were recorded before (postural activity) and during generation of occlusal force. Postural muscle activity levels prior to force generation indicated baseline activity required to maintain the mandible at each occlusal position. The same occlusal force was maintained at each position at approximately 50% of the subject's maximum incisor bite force while the average integrated EMG values for each of the eight jaw muscles was recorded. The pattern of muscle activity levels associated with each tooth position at each stage of treatment were compared among themselves and with patterns seen in controls.

3) The bite force transducer (at a height of 10mm) was placed between the patient's teeth at the central incisor and right and left molar positions. Muscle activity was then recorded during isometric bites at approximately 25%, 50%, 75%, and 100% of the maximum occlusal force at each position. At each bite force level the average integrated EMG values were recorded. Their rate of increase with increasing occlusal force was calculated. This test determined the rate at which each muscle increased activity with increasing occlusal force.

4. Patterns of muscle activity associated with the four phases of mastication of a constant bolus (Slow open, Fast open, Fast close, and Power stroke) were compared with those seen in controls and at each time interval. Average frequency and variance of the masticatory cycles were calculated.

<u>3) Measurement of Occlusal Force</u>. Occlusal force was measured using a specially designed unidirectional transducer capable of measuring force between a single pair of upper and lower teeth. During isometric bites the specified occlusal force was maintained for three seconds. Control of occlusal force during isometric bites was maintained by displaying force output on a large scale voltmeter visible to the patient. Force values during each test were entered via the keyboard to be stored with the corresponding motion and electromyographic data.

<u>4. Methods of Data Analysis</u>

The major question which was asked concerning the data collected in these studies is: 1) Do the subjective and functional evaluations differ significantly among the two condylar fracture patient groups and controls? The methods of data analysis follow:

Cephalometric Analysis

<u>Posteroanterior Cephalograms.</u> The digitized radiographs were used to determine if changes occur in the cant of the occlusal plane and the bi-gonial plane. A repeated measures analysis of variance with multiple comparisons was used to both determine the significance of changes from one interval to the next within each treatment group and to identify differences between the two patient groups over time. A significant result indicated that the curves were not parallel and therefore the two groups behaved differently.

Tomographic Analysis

The main purpose of analyzing these radiographs was to determine how similar the two patient groups were. The fracture level, dislocation, and position of the condylar head was individually subjected to a multivariate analysis of variance to determine if the two groups were significantly different.

A second use of the tomograms was to determine the significance of differences in condylar translation between the two patient groups. Tomograms allowed direct measurement of condylar translation which was not possible with the Sironathograph, which offers only indirect evidence. Measurement of condylar translation was determined by the difference in position of the mid-condylar point from the closed-mouth to the open-gape sagittal tomogram. The measures for each patient were included as a measure of mandibular motion with the other parameters of mandibular function generated by the gnathodyamic analysis for correlations (see below).

Subjective Analysis

Each of the five questions on the questionnaire were scored as even positive or negative based upon the answer given by the patient. The patient therefore could have a score of 1 to 5. A repeated measures analysis of variance on ranks were used to determine the significance of changes from one interval to the next within each treatment group and to identify differences between the two patient groups over time. A significant result indicated that the curves were not parallel and therefore the two groups behaved differently.

Gnathodynamic Analysis

For each of the measurements of range of motion (from the Sironathograph) and condylar translation measured from tomograms (see above), descriptive statistics were generated to check for normal distribution and record mean values for each patient group at each time interval. A repeated measures analysis of variance with repeated measures was used to determine the significance of changes from one interval to the next within each treatment group and to identify differences among controls and the two patient groups. A significant result indicated that the curves were not parallel and therefore the groups behaved differently.

Mean values for resting and postural levels of IEMG muscle activity of the eight jaw muscles were analyzed in the same way as the jaw motion data.

Muscle activity during biting at different tooth positions were normalized for bite force and at each time interval. Mean values of muscle activity for the fracture and non-fracture sides separately were compared between treatment groups at each time interval. Analysis of the data proceeded in the same manner as described above for mandibular motion.

The relationship between muscle activity and occlusal force was analyzed using regression analysis. The slopes of these regressions for the fracture and non-fracture sides were compared between treatment groups at each time interval for significant differences using multifactorial analysis of variance.

RESULTS

Subjects

During our four-year study we tested 99 patients after unilateral fractures of the condylar process **(Table 1)**. The majority of these patients (79) were male. Less than half of the patients (42%) chose surgical reduction of their condylar fracture.

Of those patients choosing surgical reduction, 29% were female while only 14% of those choosing non-surgical reduction were female. Male patients tended to chose non-surgical reduction (62% of males) while female patients tended to chose surgical reduction (60% of females).

Table 1. Number of cases of condylar fracture patients at each time interval. Comparing the numbers of males and females who chose surgical treatment. Open = Surgery, Closed = Non-surgery.

	Six Weeks	Six Months	One Year
Total Patients	99	69	54
Total Male Patients	79	56	43
Total Female Patients	20	13	11
Closed Reduction (M+F)	57	39	28
Open Reduction (M+F)	42	30	26
Closed Reduction (M)	49	35	26
Open Reduction (M)	30	21	17
Closed Reduction (F)	8	4	2
Open Reduction (F)	12	9	9
% Open Reduction (M+F)	42%	43%	48%
% Females with Fractures	20%	19%	20%
% Closed Reduction (F)	14%	10%	7%
% Open Reduction (F)	29%	30%	35%
% Males Open Reduction	38%	38%	40%
% Females Open Reduction	60%	69%	82%

Maximum Bite Forces (Table 2)

In both surgical and non-surgical patient groups, maximum bite forces on the fracture side were equivalent to those on the non-fracture side. Both groups steadily increased their maximum bite forces from a low at six weeks after fracture. Maximum bite forces differences between the two groups were generally less than 2 Kp and the differences were not significant for any bite position at any time interval. Power analysis indicated that, for our sample sizes, any difference between the two groups could be no larger than 4 Kp at the incisor and canine positions, no larger than 6 Kp at the premolar position, and no larger than 10 Kp at the first molar position. For almost all of the bite forces the observed difference was less than half of this upper limit difference, suggesting that there was indeed no difference between the groups. Only for the non-fracture side canine bites (difference = 3.5 Kp) at the six-month interval did the observed difference approach the upper limit difference. In this case the surgery group might have had lower bite forces than the non-surgery group.

Table 2. Median Maximum Bite Force in Condylar Fracture Patients.
Comparison between Open (Surgery) and Closed (Non-Surgery) reduction, with males and females combined.

	CLOSED			**OPEN**		
	Fracture	Non-Fracture	FR/NF	Fracture	Non-Fracture	FR/NF
Incisor						
Six Weeks	6.0	7.0	0.857	5.9	6.0	0.983
Six Months	10.0	9.0	1.111	8.0	10.1	1.250
One Year	12.3	12.2	1.008	10.0	10.0	1.000
Canine						
Six Weeks	10.0	12.0	0.833	10.0	12.0	0.833
Six Months	15.0	17.5	0.857	15.5	14.0	1.107
One Year	17.0	22.0	0.773	18.5	20.0	0.925
Premolar						
Six Weeks	18.3	15.0	1.220	15.0	17.5	0.857
Six Months	25.0	25.0	1.000	24.0	24.5	0.980
One Year	25.5	31.3	0.820	28.9	30.6	0.944
Molar						
Six Weeks	25.0	26.5	0.943	25.0	25.0	1.000
Six Months	39.0	40.0	0.975	40.0	35.5	1.127
One Year	40.0	40.0	1.000	41.5	40.1	1.035

Muscle Activity Patterns

Anterior Temporalis. Both groups generated higher levels of anterior temporalis muscle activity on the biting side (working side) than on the non-biting side (balancing side)**(Tables 3 & 4)**. This pattern was the same whether biting on the same side as the fracture or on the side opposite the fracture. There was very little difference in muscle activity levels between the two treatment groups. Only a few muscle comparisons had differences as large as 10μV. The only statistically significant difference between the two groups was for the working side anterior temporalis at the six week interval. When biting on the same side as the fracture, the surgery group had significantly less activity on the working side than did the non-surgery group. For the other cases, power analysis indicated that any differences between the two groups could be no larger than 20 μV. Because almost all of the differences were much smaller than 20 μV, we can rule out any other differences between the two groups except activity levels during molar bites at one year after surgery. In this case we cannot rule out that the non-surgery group had higher anterior temporalis activity on the side opposite the fracture, even though we found no significant difference.

Table 3. Median Anterior Temporalis Activity in Condylar Fracture Patients
Open (Surgery) vs. Closed (Non-Surgery) reduction - Biting on the Fracture Side
Males and Females Combined.

	CLOSED			**OPEN**		
	Working	Balancing	W/B	Working	Balancing	W/B
Incisor						
Six Weeks	16.40	20.00	0.820	16.35	19.05	0.858
Six Months	26.30	25.85	1.017	26.75	29.05	0.921
One Year	31.00	32.25	0.961	22.00	18.70	1.176
Canine						
Six Weeks	39.20	25.65	1.529	31.45	22.70	1.385
Six Months	45.60	27.40	1.664	40.90	36.40	1.124
One Year	51.90	48.20	1.077	49.65	41.40	1.199
Premolar						
Six Weeks	47.50*	32.35	1.468	39.75*	34.25	1.161
Six Months	56.45	46.05	1.226	52.20	47.60	1.100
One Year	58.15	46.65	1.247	64.40	49.40	1.304
Molar						
Six Weeks	53.00	42.90	1.235	45.00	43.80	1.027
Six Months	81.20	53.50	1.518	66.50	50.10	1.327
One Year	68.55	55.90	1.226	69.25	78.05	0.887

* Significant difference between groups at p=0.039.

Table 4. Median Anterior Temporalis Activity in Condylar Fracture Patients
Open (Surgery) vs. Closed (Non-Surgery) reduction - Biting on the Non-Fracture Side
Males and Females Combined.

	CLOSED			**OPEN**		
	Working	Balancing	W/B	Working	Balancing	W/B
Incisor						
Six Weeks	23.00	19.10	1.204	18.10	17.10	1.058
Six Months	25.55	26.05	0.981	32.50	21.25	1.529
One Year	38.20	32.25	1.184	28.60	22.40	1.277
Canine						
Six Weeks	33.60	18.60	1.806	39.60	17.30	2.289
Six Months	47.50	30.50*	1.557	47.25	23.65*	1.998
One Year	58.90	40.15	1.467	68.35	27.65	2.472
Premolar						
Six Weeks	46.40	26.15	1.774	44.50	26.10	1.705
Six Months	59.75	40.40	1.479	57.75	39.50	1.462
One Year	71.70	46.75	1.534	66.60	42.40	1.571
Molar						
Six Weeks	58.75	43.30	1.357	53.85	36.60	1.471
Six Months	69.30	53.05	1.306	71.00	64.95	1.093
One Year	80.00	48.40	1.653	100.00	56.00	1.786

* Significant difference between groups at p=0.015.

Superficial Masseter. The activity patterns of the superficial masseter muscle were more complex **(Tables 5 & 6).** When biting on the side of the fracture, both groups tended to have balancing side activity that was equal to or higher than the working side activity. In contrast, when biting on the side opposite the fracture, both groups had substantially greater activity on the working side. These results indicate that activity was generally lower in the masseter on the side of the fracture. This difference between the fracture side masseter and the non-fracture side masseter was greatest at six weeks and gradually became less of a difference at later time intervals.

However, none of the muscle comparisons was significantly different between the two groups. Only a few of the differences were as large as 20 μV. As with the anterior temporalis, power analysis indicated that any differences between the two groups could be no larger than 20 μV. Therefore, we can rule out any differences in masseter activity between the two groups except for a few cases when biting on the same side as the fracture.

During fracture-side canine bites at the one-year period, the non-fracture group may have had higher masseter activity on both the working and balancing sides. This is surprising because the bite forces of the non-surgery group, at that time interval, was only 1.5 Kp larger than that of the surgery group.

At the six-month interval the non-surgery group may have had greater masseter activity on the balancing side during molar bites on the non-fracture side. However, at one year this pattern disappeared and the surgery group now had greater activity on the working side than did the non-surgery group.

In summary, evidence for any differences in muscle activity patterns between the treatment groups is not compelling.

Table 5. Median Superficial Masseter Activity in Condylar Fracture Patients
Open (Surgery) vs. Closed (Non-Surgery) reduction - Biting on the Fracture Side
Males and Females Combined.

	CLOSED			**OPEN**		
	Working	Balancing	W/B	Working	Balancing	W/B
Incisor						
Six Weeks	19.60	31.00	0.632	17.15	33.10	0.518
Six Months	34.20	46.30	0.739	38.85	42.70	0.910
One Year	51.00	50.45	1.010	40.60	52.40	0.775
Canine						
Six Weeks	27.90	34.30	0.813	24.80	34.85	0.712
Six Months	34.90	51.30	0.680	48.55	55.25	0.879
One Year	46.40	47.90	0.969	66.10	71.90	0.953
Premolar						
Six Weeks	37.90	43.70	0.867	33.80	44.50	0.760
Six Months	61.10	57.95	1.054	63.10	63.70	0.991
One Year	63.45	58.75	1.080	66.10	71.90	0.919
Molar						
Six Weeks	51.00	48.80	1.045	46.00	51.50	0.893
Six Months	84.05	60.80	1.382	76.45	80.10	0.954
One Year	83.15	70.15	1.185	57.10	69.00	0.828

Table 6. Median Superficial Masseter Activity in Condylar Fracture Patients
Open (Surgery) vs. Closed (Non-Surgery) reduction - Biting on the Non-Fracture Side
Males and Females Combined.

	CLOSED			**OPEN**		
	Working	Balancing	W/B	Working	Balancing	W/B
Incisor						
Six Weeks	35.30	22.50	1.569	30.10	18.50	1.627
Six Months	37.80	37.05	1.020	43.35	41.75	1.038
One Year	53.15	51.40	1.034	45.35	40.25	1.127
Canine						
Six Weeks	38.40	27.00	1.422	45.60	30.50	1.495
Six Months	46.00	40.30	1.141	50.95	46.50	1.096
One Year	61.25	52.25	1.172	51.40	52.75	0.974
Premolar						
Six Weeks	45.15	29.50	1.531	49.90	31.20	1.599
Six Months	51.55	42.35	1.217	69.00	58.60	1.177
One Year	72.00	66.00	1.091	73.30	53.10	1.380
Molar						
Six Weeks	53.15	32.30	1.646	57.30	43.35	1.322
Six Months	70.00	79.35	0.882	67.75	83.20	0.814
One Year	88.90	62.70	1.418	85.00	56.70	1.499

Maximum Voluntary Ranges of Motion (Table 7).

Both groups had reduced mobility at six weeks after the fracture, and both groups had close to normal mobility at six months and one year after the fracture. The reduced mobility was most apparent during maximum opening. Both groups had some lateral deviation on opening, but deviation in the non-surgery group was toward the fracture side while deviation in the surgery group was away from the fracture side. This difference was not apparent at the six weeks period, but was a significant difference at six months and one year after the fracture.

Both groups had greater excursions toward the fracture side than away from the fracture side, although at six weeks and six months, the surgery group tended to have a smaller difference between the two excursions. This difference between the two groups was not significant and at one year had disappeared. The surgery group also tended to have greater maximum protrusion than the non-surgery group. This difference approached significance at the six month and one-year time intervals ($p=0.070$ and $p=0.087$, respectively). Both groups initially exhibited deviation toward the fracture side during protrusion. This deviation was maintained in the non-surgery group but tended to disappear in the surgery group.

With the exception of lateral deviation on opening, most of the differences between the two groups were less than 2.0 mm of excursion. Power analysis indicated that our sample size was insufficient to rule out differences this small during maximum opening. However, sample sizes were adequate to rule out differences of less than 2 mm for the lateral excursion and protrusion measurements. Therefore, we can conclude that the two groups differed for lateral deviation on opening, and we cannot rule out other differences in opening.

Table 7. Voluntary maximum excursions in condylar fracture patients at each time interval. Comparing Closed (Surgery) and Open (Non-Surgery) reduction.

	Six Weeks	Six Months	One Year
Closed Redn: Interincisal Opening	35.6	41.0	38.2
Open Redn: Interincisal Opening	34.7	38.3	39.8
Closed Redn: Vertical Opening	30.3	33.8	30.3
Open Redn: Vertical Opening	28.8	30.8	30.9
Closed Redn: Posterior Opening	18.3	21.5	20.8
Open Redn: Posterior Opening	17.1	20.6	21.7
Closed Redn: Lateral Deviation	-0.2	2.3*	2.5
Open Redn: Lateral Deviation	-0.8	-2.3*	-2.3
Closed Redn: Excursion to Fracture Side	9.4	10.0	9.4
Open Redn: Excursion to Fracture Side	10.0	10.4	10.6
Closed Redn: Excursion From Fracture Side	7.7	8.8	9.4
Open Redn: Excursion From Fracture Side	8.1	10.1	8.8
Closed Redn: Protrusion	5.6	6.0	6.3
Open Redn: Protrusion	6.9	7.9	7.7
Closed Redn: Lateral Deviation on Protrusion	3.8	2.5*	2.9
Open Redn: Lateral Deviation on Protrusion	2.7	-1.3*	1.0

* Significant difference between groups at p=0.014
** Significant difference between groups at p=0.045

Excursions During Mastication (Table 8)

Based on the trace of the frontal projections of jaw movements during mastication, each subject was scored as +1.0 if their mandible moved laterally primarily toward the side of the fracture, a -1.0 if they moved to the side opposite the fracture, and 0 if they showed no preference in deviation of the jaw during mastication. An average close to 0 would indicate that, as a group, patients showed no preference in jaw deviation during mastication relative to the side of fracture.

The surgery group tended to chew more often on the side with the fracture, while the non-surgery group showed no preference for chewing side. Both groups had slightly smaller maximum opening during mastication at the 6-weeks interval than at six months and one year after the fracture. However, the mean masticatory opening did not show this pattern. Both groups had slightly greater maximum and mean lateral excursions at 6 weeks than at the two later time periods.

Many of the masticatory excursions were slightly smaller in the surgery group, however, none of the differences was statistically significant. All of the differences between the two groups were less than 2 mm except for interincisal opening at the 6-month interval, and most differences were less than 1 mm. Power analysis indicated that any differences between groups could be no greater than 2mm, except for interincisal opening where it could be no greater than 3 mm.

Table 8. Masticatory excursions in condylar fracture patients at each time interval. Comparing Closed (Surgery) and Open (Non-Surgery) reduction.

	Six Weeks	Six Months	One Year
Closed Redn: Deviation during Chewing	0.254	0.128	0.148
Open Redn: Deviation during Chewing	0.085	0.000	0.080
Closed Redn: Interincisal Opening	18.7	20.7	19.5
Open Redn: Interincisal Opening	17.6	18.3	18.2
Closed Redn: Vertical Opening	15.9	18.1	16.9
Open Redn: Vertical Opening	15.6	16.5	16.6
Closed Redn: Posterior Opening	8.5	11.9	12.3
Open Redn: Posterior Opening	8.1	12.3	11.0
Closed Redn: Lateral Excursion	11.9	9.4	8.1
Open Redn: Lateral Excursion	10.1	8.1	8.1
Closed Redn: Mean Vertical Excursion	12.2	11.6	11.6
Open Redn: Mean Vertical Excursion	11.9	10.3	10.9
Closed Redn: Mean Posterior Excursion	4.4	4.4	4.3
Open Redn: Mean Posterior Excursion	4.2	3.9	5.0
Closed Redn: Lateral Excursion	4.8	4.4	4.5
Open Redn: Lateral Excursion	4.4	3.8	4.2

Data Not Yet Analyzed

Although the bulk of the data has been analyzed (above), there is a quantity of data that has yet to be analyzed. A more detailed analysis of the duration of chewing cycle phases, mandibular excursions, and muscle activity patterns during mastication are not yet complete. This analysis uses the special computer program (MAS) developed for this project. The MAS program develops more than 500 measurements of the chewing cycle. This analysis will be completed during the coming year.

We have not yet begun to perform the radiographic analysis. This project will take a considerable amount of time and we are going to begin analyzing the radiographs in the coming year, as we are still acquiring radiographs on follow-up patients.

We have not yet analyzed the subjective data acquired from the patients at each time point. This data will be evaluated in the coming year in concert with the radiographic findings.

We also wish to determine how much postsurgical management time was required for both treatment groups. It is our feeling that treatment of patients without surgery requires many more visits, for longer periods of time than those treated open. It is also our opinion that the occlusal results are more predictable with open surgery. We hope to assess this based upon our occlusal photographs in the future.

Questions Answered

For purposes of this report, we have concentrated on analysis of the functional parameters that were noted in patients with fractures of the mandibular condyle treated either open or closed. We have satisfactorily addressed the following questions:

Question 1: Are there reductions in maximum range of motion in both treatment groups? Is this reduction less in the open reduction group?

Our results indicate that both patient groups differ significantly from controls in several measures but from one another only in the amount of lateral deviation during maximal opening (Table 7). Those patients treated without surgery showed significant deviation toward the side of fracture. This suggests that the fractured condyle does not translate as well as the contralateral condyle. Those patients treated open showed more deviation away from the side of fracture indicating that their fractured condyle translated as well or better than their contralateral condyle. Both groups showed similar reductions in interincisal opening, excursion away from the fracture side, and protrusion. These changes appear to be independent of the type of treatment.

Question 2: Are there limitations in range of motion or changes in muscle activity patterns during mastication?

The ranges of motion during mastication were nearly equivalent in both patient groups to those of controls (Table 8). These results suggest that both methods of treatment return patients to normal ranges of opening and posterior excursion within 6 to 8 weeks following fracture. Differences in muscle activity patterns await future analysis.

Question 3: Are there reductions in maximal occlusal force generation or reduction of muscle efficiency at submaximal occlusal forces.

The ability to generate occlusal force was determined while biting at the incisors, canines, first premolars and first molars bilaterally. Statistical comparison between the two groups was made using ANOVA. These results indicate that there was no significant difference in the two treatment groups' ability to generate occlusal force (Table 2). But both groups had lower than normal bite forces, generally about half of normal values, although bite forces improved at one year.

Question 4: Are there changes in muscle activity patterns related to protecting the fractured joint from loading?

The electromyographic activity in the anterior temporalis and masseter muscles was recorded during isometric incisor bites are reported in Tables 3 & 4. When compared to controls, patients in both groups tended to have lower levels of activity during isometric bites, reflecting their lower levels of occlusal force. There was no consistent indication that working/balancing ratios of the temporalis were altered during isometric bites in either group of fracture patients. However, in both groups of patients the non-fracture side muscle had higher activity than the fracture side masseter. Normally, during isometric bites, balancing side masseter activity is equal or slightly less than working side masseter activity (Throckmorton et al., 1990). Therefore, the working/balancing ratio should be approximately 1.0 regardless of the biting side. In the fracture patients at six weeks and six months after surgery, the W/B ratio was significantly less than 1.0 when biting on the fracture side and significantly less than 1.0 when biting on the non-fracture side. This change in relative muscle activity would reduce the load on the fractured and healing condyle. Such a shift would indicate attempts to prevent loading of the fractured joint. Joint loads are also minimized by reducing occlusal forces. These preliminary results suggest that muscle activity patterns during isometric bites are affected by the initial injury but are not affected by the method of treatment.

Summary of Results and Relevance

The major preliminary findings of this investigation are that the patients treated by closed reduction have a significantly deviation toward the side of the fracture when opening the mouth. This was not only different from controls, but from patients treated by open reduction, who tended to deviate slightly the toward the unaffected condyle. This indicates that the fractured condyle does not translate well when treated without surgical repositioning and stabilization. The long term effects of this could not be assessed in this study, nor could it be determined whether or not this finding will be present in the patients followed up for a longer period of time, for instance, 20 years. We suspect that the deviation toward the side of the fracture will be permanent, as other studies have shown. Whether or not this aberrant pattern of motion will lead to degenerative joint disease in either the fractured or contralateral TMJ is not known.

What has never been shown in past studies is the ability of open reduction and internal fixation of the fractured condyle to provide normal mandibular mobility. We are very pleased with this finding, and have been gratified by the ability of patients treated by open reduction to produce normal mandibular excursion as little as four weeks postsurgery. We have found that this group of patients required less careful follow-up than the closed reduction group because the proper use of elastic traction between the upper and lower teeth for control of the occlusion has been unnecessary in the open reduction patients. Reduction and fixation of their fracture condyle has provided these patients with their pre-traumatic occlusion--no postsurgical elastic guidance of the occlusion was used in any patient.

CONCLUSIONS

The results of this investigation show that there are minor differences between patients with condyle fractures treated by closed or open reduction. Further, patients in both groups, at least at 6-8 weeks postsurgery, differ in many variables from controls. The results of our analysis to date do not indicate strong functional reasons for treating patients with open reduction vs. closed reduction. However, we cannot rule out finding such reasons after our data analysis is complete. We re especially concerned that functional differences may be more apparent when the degree of condylar displacement is factored is factored into our analyses. In addition, the postsurgical management of those patients treated with surgery was simplified, and the occlusal results were more satisfactory, even early in the postoperative time period.

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