THE ROLE OF ORTHODONTIC TREATMENT AND MALOCCLUSION IN THE ETIOLOGY OF MANDIBULAR DYSFUNCTION

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by

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ABSTRACT

In recent years more patients than ever before are seeking treatment for symptoms of mandibular dysfunction. An observation that many of these individuals have had previous orthodontic treatment has led some dental clinicians to believe that orthodontic treatment may cause mandibular dysfunction.

The present study was undertaken to examine the incidence of mandibular dysfunction in young adults who had orthodontic treatment in comparison to those who had not. The same study explored the incidence and nature of dysfunction in the teenage and young adult population to determine the influence of occlusal factors on the dysfunction state.

A total of 371 subjects in two major groups were examined. The treated group consisted of 170 subjects treated with full-banded edgewise appliances. The mean age was 18.5 years, and the male:female ratio was 1:2.5. Of these, 137 had received treatment at the University of Manitoba Graduate Orthodontic Clinic and 33 were treated in private practice. The latter group was examined at a city high school and another university. The control group consisted of 201 untreated subjects of mean age 17.3 years and male:female ratio of 1:1.7. Of these, 62 had sought treatment for malocclusion at the University of Manitoba Graduate Orthodontic Clinic, and 139 were examined in two high schools and the other university.

An anamnestic examination (oral history) and a clinical

examination were carried out on each subject. The data gathered was grouped and classified using various indices and then statistically analysed. The findings warrant the following conclusions:

1. Mandibular dysfunction was a common occurrence in the population sampled. In the anamnestic examination, 58% of all subjects reported at least one symptom of dysfunction, while in the clinical examination, one or more dysfunction signs were found in 68% of the subjects. Forty-four percent of the subjects had both dysfunction symptoms and signs. Most dysfunction found was of a minor nature. Of the 304 subjects who were found to have at least one symptom or sign of dysfunction, only 13% required treatment according to the subjective assessment of the examiner.
2. Females suffered somewhat more from dysfunction than did the males. Clinical evidence of clicking was 68% higher in females ($p < .01$), while signs and symptoms of pain were about 14% higher ($p < .001$). Most other dysfunction factors were higher for females, though not at the level of statistical significance.
3. Dysfunction signs and symptoms increased with age. In comparing the 12-15 years group with the 20-30 years group, pain signs increased by 39%. Crepitus increased fourfold ($p < .01$). Limitation of jaw movement increased by 62% ($p < .001$).
4. Subjects with dysfunction had significantly higher incidences ($p < .001$) of headache, neck, and back pain. General joint symptoms were also related to dysfunction.
5. There was a weak association between static malocclusion and

dysfunction. A similar association existed when comparing static malocclusion to functional occlusal discrepancies, such as balancing contacts, lateral centric slides, and unusual lateral guidance (e.g. guidance by only one posterior tooth).

6. There was a weak association between balancing contacts, and mandibular dysfunction. There was no association between the length or direction of centric slides and dysfunction.

7. For functional factors, it was found that the mean length of lateral and anterior centric slides were slightly higher for the treated group, while the incidence of balancing contacts was higher for the control group, as was the incidence of unusual types of lateral guidance.

8. Orthodontic treatment was not found to be an etiological factor in mandibular dysfunction. Dysfunction symptoms reported in the anamnestic examination were more prevalent in the control than the treated group. There was no difference between the control and treated group for dysfunction signs found in the clinical examination.

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TABLE OF CONTENTS

LIST OF FIGURES

Figure | Page

LIST OF TABLES IN THE TEXT

LIST OF TABLES IN THE APPENDIX

Table		Page

INTRODUCTION

It was less than fifty years ago that Costen (1934) wrote the article which first stimulated interest in mandibular dysfunction (for some time referred to as "Costen's syndrome"). The apparent increase in the incidence of dysfunction in recent years has stimulated clinicians and researchers to investigate the extent and nature of dysfunction in the general population and to attempt to determine possible etiological factors.

Most of the early studies on the epidemiology of mandibular dysfunction were carried out on clinical patients who had sought treatment for dysfunction symptoms. A high proportion of these patients were females in the 20 to 50 year age group. More recently, a number of studies have been carried out on various groups of non-clinical subjects. These latter studies have shown that the signs and symptoms of mandibular dysfunction are common in the general population and there is no great difference in prevalence between the sexes and among the various age groups. In surveys of both clinical and non-clinical subjects, there was found a relationship between dysfunction and general joint and muscle symptoms.

An observation that a high proportion of patients seeking treatment for dysfunction symptoms had previous orthodontic treatment has led Shore (1976) and other clinicians to believe that orthodontic treatment is a common cause of mandibular dysfunction. They see the increase of orthodontic treatment in recent years as an important factor in the apparent increasing incidence of mandibular dysfunction. The dysfunction is thought to be caused by functional occlusal discrepancies resulting from poor orthodontic finishing.

Few studies have actually been carried out to adequately examine the relationship of orthodontic treatment to dysfunction. The apparent association may be coincidental rather than causal. The relationship of dysfunction and functional occlusal factors, although examined, remains controversial as well. The relationship of dysfunction and static malocclusion (the traditional orthodontic view of malocclusion) has not been adequately examined. The incidence of mandibular dysfunction in the teenage population, the age group of most orthodontic patients, requires further documentation.

This research was conceived with the intent of furthering knowledge in these uncertain areas. In point summary the purposes of this study are as follows:

1. To examine the effect of orthodontic treatment on mandibular dysfunction by comparing the incidence of dysfunction in a group treated orthodontically and an untreated control group.
2. To compare the treated and control groups for the functional aspects of malocclusion.
3. To examine the relationship between functional occlusal factors and dysfunction.
4. To examine the relationship between static malocclusion and dysfunction.
5. To determine the incidence of dysfunction in the teenage and young adult population.

6. To examine the relationship of age and sex to mandibular dysfunction.
7. To examine the relationship of dysfunction to general joint and muscle symptoms.

REVIEW OF THE LITERATURE

Etiology of Mandibular Dysfunction

Dysfunction of the masticatory system is a well-described phenomenon in the dental literature. Because certain signs and symptoms of masticatory dysfunction often occur together, they are said by some to constitute a syndrome. This "syndrome" goes by many names, the more common of which are: Temporomandibular Joint Pain-Dysfunction Syndrome (Schwartz and Chayes, 1968); Mandibular Pain-Dysfunction Syndrome (MDS) (Molin, 1973); Temporomandibular Joint-Dysfunction Syndrome (Shore, 1959); and Myofascial Pain-Dysfunction Syndrome (MPD) (Laskin, 1969).

In this paper the term "mandibular dysfunction" will be used to describe dysfunction of the masticatory system. Temporomandibular joint will be abbreviated to "TMJ".

Some authorities, however, believe that to use the term "syndrome" in describing mandibular dysfunction implies one particular disorder with a single etiology. Zarb and Speck (1979) and Rugh and Solberg (1979) see masticatory dysfunction not as a single specific disease entity, but rather as a group of unrelated disorders with multifactorial etiology. "Mandibular dysfunction is not a syndrome but a spectrum of syndromes" (Storey, 1979).

There is agreement among many investigators in the field that the presence of the following signs and symptoms is pathognomonic for the existence of mandibular dysfunction:

1. pain in the region of the muscles of mastication and/or the temporomandibular joint

2. limitation of mandibular movement

3. temporomandibular joint sounds during mandibular movement (Bell, 1969; Greene et al., 1969; Laskin, 1969; Griffin and Munro, 1971; Hanson and Oberg, 1971; Posselt, 1971; Solberg et al., 1972; Agerberg and Carlsson, 1973; Zarb and Thompson, 1975; De Boever, 1979). According to Rugh and Solberg (1979), joint sounds alone are not generally considered sufficient evidence for specifying the dysfunctional state.

a) Theories of Etiology of Dysfunction

The signs and symptoms of mandibular dysfunction may be the result of pathologic changes within the joints, muscles and connective tissues of the masticatory system. Stretching or tearing of the joint capsule due to trauma may give rise to pain and limitation of mandibular movement. Muscle splinting to ease the painful joint may contribute to a further restriction of mandibular movement. Trauma to muscles and tendons may also cause pain and limit mandibular mobility, as may muscle spasm due to hyperactivity. Hyperactivity and spasm may cause unco-ordinated function of the two heads of the lateral pterygoid muscle which in turn may lead to clicking of the TMJ (Toller, 1974). Arthritic changes to the joint may lead to crepitus and ultimately to pain and restriction of jaw movement.

Varying theories of the etiology of pathological changes to the masticatory system have been developed. For the sake of discussion these theories of etiology can be grouped in four categories:

i. Inflammatory Arthritis Theory

ii. Traumatic Theory

iii. Psychologic Theory

iv. Functional Theory

i. Inflammatory Arthritis Theory

Rheumatic and infectious arthritis fall under this category. Rheumatoid arthritis (RA) is a systemic condition of unknown etiology. The incidence of RA is low in children but increases substantially with age, so that 2.5% of the population over 20 years has RA (Allander, 1970). TMJ involvement varies from 2 - 86% in different studies (Carlsson et al., 1979). Because the incidence of RA is very much less than the incidence of TMJ pain and dysfunction, RA is not likely a significant factor in the majority of cases of mandibular dysfunction.

Infectious arthritis of the TMJ occurs with even less frequency and is also not considered significant in most cases of mandibular dysfunction.

Unlike rheumatoid and infectious arthritis, osteoarthritis (arthrosis deformans) appears to have a functional etiology. Osteoarthritis is a non-inflammatory disease characterized by degeneration of the articular joint surfaces and remodelling of the underlying bone. It will be discussed further under the topic "Bruxism".

ii. Traumatic Theory

Speck and Zarb (1976) divide trauma into microtrauma and macrotrauma. Microtrauma is caused by persistent multiple minor traumas due to occlusal discrepancies, parafunction, and irregular opening and closing patterns. These etiological factors will be discussed in conjunction with the psychologic theory, functional theory, and bruxism.

Macrotrauma is a result of a sudden abnormal pressure which may stretch and tear joint capsules and injure muscles and tendons. Based on case histories, Speck and Zarb (1976) noted that this type of injury may be due to factors such as a blow to the jaw, heavy pressures in extraction of lower molars, or mandibular deflection caused by a new dental restoration. Even a sudden wide opening of a hypermobile joint may also produce a spontaneous strain. Other investigators (Greene et al., 1969; Carlsson and Svardstrom, 1971; Solberg et al., 1972) have found that some symptomatic patients were able to trace the onset of dysfunction to a particular episode of macrotrauma.

iii. Psychologic Theory

This theory emphasizes the importance of centrally-initiated hyperactivity of the masticatory muscles. Newton (1969), Laskin (1969) and Yemm (1979) are proponents of this theory.

Psychologic stress and emotional states such as anxiety elicit muscular tension often manifest as clenching and bruxism. The persistent muscle tension leads to spasm and pain of the muscles of mastication. Altered muscle function may also lead to functional malocclusion (Laskin, 1969).

Travell (1960) cites clinical evidence to show that emotional stress, as well as noxious stimuli, can underlie the development of spasm of muscles particularly in the head and neck. The resulting pain may be referred to the area of the muscles of mastication or TMJ.

Studies by Molin and Levi (1966), Lupton (1969), Rothwell (1972), and Clark et al. (1977) have shown a positive relationship between emotional stress and mandibular dysfunction. It is of interest to note that some investigations have found that patients with mandibular dysfunction commonly suffer from symptoms such as headache (Posselt, 1971; Helkimo, 1976; Dawson, 1974; Agerberg and Carlsson, 1975; Molin et al., 1976; Speck and Zarb, 1976) and general muscle symptoms (Berry, 1969; Helkimo, 1976; Molin et al., 1976). These symptoms may likewise be related to muscle tension of psychologic origin.

iv. Functional Theory

The functional theory emphasizes the importance of functional disharmony between the dental occlusion and TMJ. Occlusal interferences such as balancing-side contacts and discrepancies between centric relation and centric occlusion, do not allow the TMJs to assume their ideal positions. The musculature will be forced to move the mandible according to the dictates of the occlusion instead of the joints. Reflexes may be established to avoid these interferences, but the chronic muscle activity induced may lead to pain, fatigue and spasm of the masticatory muscles (Ramfjord and Ash, 1971). Interferences sufficiently severe may also cause microtrauma or macrotrauma to the TMJ and related structures. These interferences may also trigger bruxism in some individuals (Ramfjord, 1961).

Abundant clinical evidence exists to show that occlusal equilibration to harmonize the occlusion with the TMJs often leads to alleviation of dysfunction symptoms. This observation has made the Functional Theory the prime etiologic theory in the opinion of clinical dental practitioners such as Guichet (1970) and Dawson (1974).

b) Bruxism and Mandibular Dysfunction

Although the Psychologic and Functional theories differ as to whether the trigger for dysfunction is based centrally in the nervous system, or locally in the masticatory system, both theories emphasize that parafunctional behavior and particularly bruxism may be an important factor leading to dysfunction.

The epidemiologic studies of Agerberg and Carlsson (1975) and Solberg et al. (1979) have shown that a significant number of subjects with dysfunction reported a history of bruxism. Ramfjord (1961) and Lindqvist (1974) reported clinical evidence of bruxism (bruxofacets) in many symptomatic individuals.

Vestergaard Christiansen (1975) found that one-half hour of voluntary bruxism in otherwise healthy, asymptomatic individuals can produce painful symptoms similar to those reported by dysfunction patients. These symptoms lasted as long as several days.

In a recent review of arthritis and the TMJ, the importance of bruxism was noted. "Functional overloading during mastication and/or parafunction, such as bruxism, plays a fundamental role in the cause and progression of osteoarthrosis of the TMJ" (Carlsson et al., 1979). They also concluded that while crepitus is the most reproduceable sign of osteoarthritis of the TMJ, pain and restriction of jaw movement may also result from arthritic changes.

c) Summary

In summary, there are various theories of the etiology of mandibular dysfunction. It seems unlikely that any single etiological factor is responsible for the signs and symptoms of mandibular dysfunction. Rugh and Solberg (1979) summarize a viewpoint presently held by many investigators in the field of dysfunction.

> Conclusive evidence that there is one major cause for TMJ disorders is absent, even though there are abundant claims

to the contrary. The probability that any one patient will present dysfunctional symptoms is clearly dependent upon a staggering number of factors, many of which are not well understood. The unitary concept (one cause - one disease) must therefore be discarded in favor of the more applicable multifactorial concept (several harmful factors act upon an organ system at the same time).

Orthodontic Treatment and Mandibular Dysfunction

a) Orthodontic Treatment as a Cause of Dysfunction

Whether orthodontic treatment can lead to dysfunction remains controversial. Some clinicians have assumed there exists an association between orthodontic treatment and dysfunction, as many patients who exhibit signs and symptoms of dysfunction at ages 20 to 40 have had orthodontic treatment during adolescence (Williamson, 1977). Orthodontic clinicians and others have observed that after treatment patients may develop symptoms of mandibular dysfunction (Thompson, 1956; Roth, 1973; Perry, 1976; Williamson, 1976; Aubrey, 1978).

Shore (1976) cites orthodontic treatment as a factor in the increasing incidence of patients with mandibular dysfunction. He states that in the past 95% of patients were females usually of age 35 to 45. More recently, males now make up 25% of this group, and some patients are as young as 10 years. He believes this change is due to two factors: increasing stress at a younger age leads to bruxism; secondly, the incidence of orthodontic treatment has increased dramatically in the last ten years. Many of these cases lack proper finish, or they relapse and do not receive occlusal equilibration. The resulting occlusal interferences may ultimately lead to dysfunction.

Shore apparently bases these remarks on clinical observation. No specific study to test his hypotheses was reported.

In a study done in Britain, Franks (1967) implicated orthodontic treatment as a possible cause of mandibular dysfunction. He found in a study of 751 patients with dysfunction that 11% of these patients had undergone orthodontic treatment in comparison with 2% in a control group of patients receiving routine dental care.

Some orthodontists agree that orthodontic treatment may have the potential for causing mandibular dysfunction. During orthodontic treatment, and particularly in extraction cases where more tooth movement is needed, the changing occlusal relationships require a series of neuromuscular adaptations. If the capacity of the masticatory system to adapt is exceeded, dysfunction and pain may result (Perry, 1973). Ricketts (1966) observed that clinical symptoms of dysfunction are, in fact, sometimes seen as occlusions are changed.

Perry (1969) studied 1146 patients with malocclusions undergoing orthodontic treatment. He found that 3% had one or more symptoms of mandibular dysfunction prior to treatment, an additional 5.1% developed symptoms during active therapy and 7.4% more first noticed symptoms during retention. Thus a total of 15.5% had symptoms during therapy. However, after retainers were removed, only 5.1% continued to have symptoms.

Orthodontists have been blamed by some dental clinicians for creating occlusions which leave patients susceptible to mandibular dysfunction (Roth, 1972). Speck and Zarb (1976) note that after inadequate orthodontic treatment, some patients may lack a definite centric occlusion. The result is erratic mandibular movements as the jaw seeks a position of comfort in which to close. These chronic erratic movements may cause masticatory muscle spasm and incoordination, and lead to subsequent stretching of the joint capsule.

Roth (1973) studied the effect of occlusal equilibration on 7 post-orthodontic patients suffering from one or more of pain, clicking, and limitation of mandibular movement. He used two asymptomatic treated patients as controls. On examination of the occlusion, he found that all symptomatic subjects had balancing interferences, while neither of the control subjects did. The subjects with the severest symptoms had the greatest degree of centric slide as well as balancing and/or protrusive interferences. After occlusal adjustment, all subjects had complete alleviation of symptoms.

The small number of subjects and the lack of a random selection process used in this study make firm conclusions difficult. Even mock occlusal equilibration may alleviate the symptoms of mandibular dysfunction in some patients, thus emphasizing the importance of non-occlusal factors (Goodman et al., 1976). However, occlusal factors no doubt play an important role in the etiology of dysfunction (Ramfjord and Ash, 1971).

It is not only occlusion which may be altered by orthodontic treatment. In a review of the pertinent literature, Carlsson and Oberg (1979) concluded that "there is convincing evidence that remodelling activities can be stimulated in the condyle in young as well as in full-grown animals by the effect of an appliance used to displace the lower jaw." Breitner (1940) found that both Class II and Class III elastics caused remodelling of the TMJ in monkeys. In general these changes in the TMJ appear to take place without obvious pathology. It is not presently knwon whether TMJ remodelling occurs in humans as a result of orthodontic treatment.

b) Orthodontic Treatment as an Unlikely Cause of TMJ Dysfunction

There is also evidence to show that patients treated orthodontically are no more likely to experience mandibular dysfunction than are untreated individuals.

An apparent increase in the number of young patients referred for treatment of masticatory dysfunction, and the observation that many of these patients had previously received orthodontic treatment, led to a study by Dorph et al. (1975). They found that among 105 patients aged 14-25 being treated for subjective symptoms of masticatory dysfunction, 28.6% reported previous orthodontic treatment. In an asymptomatic control group, 26.4% had orthodontic treatment. Since there was no significant difference in incidence between the two groups, they concluded that their study "did not support the hypothesis that orthodontic treatment was responsible for an observed increase in the number of young patients referred for subjective symptoms of masticatory dysfunction."

Dibbets (1977) studied a group of 112 children age 10 to 17 with Angle Class II Division 1 malocclusion who received orthodontic treatment with activators and Begg appliances. The children were examined regularly during treatment for signs and symptoms of dysfunction. Radiographs of the TMJs were also taken at regular intervals during treatment using the Parma projection (Parma, 1932) to diagnose morphological changes of the condyle and glenoid fossa (arthrosis deformans juvenilis). Because it is difficult to distinguish "treatment complaints" from serious disturbances of the TMJ, he felt that diagnosis of pathology using the radiographs alone would be much more reliable. He concluded that orthodontic treatment was not a predisposing cause for "arthrosis deformans juvenilis."

Barghi (1978) examined 500 "young subjects" composed of dental students, dental assistant students, and patients, in order to evaluate the influence of occlusion and other factors on mandibular dysfunction. Of the total sample group, 24% "had received the various types of orthodontic treatment." He found that the subjects treated orthodontically had no higher incidence of masticatory muscle spasm or TMJ pain than did the untreated subjects.

c) Mandibular Dysfunction Prior to Orthodontic Treatment

As a further complication to assessing the effects of orthodontic treatment on jaw dysfunction, there exists the possibility that even young patients may exhibit the signs and symptoms of jaw dysfunction prior to orthodontic treatment (Watson, 1979). Brussell (1949) studied 50 children age 12 to 14 who required orthodontic treatment. He stated that 18 (36%) had at least two symptoms involving the joint, which was characterized by "crepitus and luxation in one or both joints, with the beginning of jerky movements of the mandible on opening widely."

In a survey of 129 male and 175 female applicants screened for orthodontic treatment at a university orthodontic department, Williamson (1977) found a surprisingly high incidence of jaw dysfunction. He palpated the muscles of mastication and monitored joint sounds. Thirty-five per cent of the subjects exhibited pain and/or clicking unilaterally or bilaterally. Of these, 7% had only clicking. The lateral pterygoid muscle was most often sensitive to palpation, followed by the medial pterygoid muscle. Of the symptomatic subjects, 17% had an open bite, 54% had greater than 50% overbite, and the mean overjet was 3.75 mm. Williamson notes that these young patients exhibit the same patterns of malocclusion as adult dysfunction patients, in that many have either steep mandibular planes and Class II Division 1 malocclusions with anterior open bites, or flat mandibular planes and Class II Division 2 malocclusions with deep overbite. "The incipient joint problem at the ages 6 to 16 will likely be the one overtly seen at the age of 30, whether orthodontic treatment has been rendered or not."

In the malocclusion group which Dibbets (1977) studied, he reported that prior to treatment 46% had "temporomandibular joint dysfunction." He defined the dysfunction as consisting of subjective or objective symptoms of joint sounds, TMJ pain, luxation or limitation of jaw movement, as well as the presence of "arthrosis deformans juvenilis" (as previously defined). Of particular note is the increase in incidence of "arthrosis deformans juvenilis" (ADJ) with age. Prior to treatment the incidence was less than 5% at age 10 but over 20% at age 17. The mean incidence for the entire group prior to treatment was 16% and increased to 24% two years after the beginning of treatment. He attributed the increase in ADJ to the increased age of the sample group rather than to the influence of orthodontic treatment. There is no mention made of change in the incidence of temporomandibular joint dysfunction. He also found no relationship between ADJ and sex.

Wigdorowicz-Makowerowa et al. (1979) examined 4924 subjects age 10 - 45 made up of school children, medical students, and soldiers. They found that for all groups studied, "TMJ dysfunctions were about twice as frequent in groups with malocclusion than in those without malocclusion." Unfortunately, what the authors meant by the term "malocclusion" was never defined. Bruxism was 1.4 times as frequent for malocclusion groups as well.

In a study on 287 army conscripts of average age 18, Ingervall and Hedegard (1974) noted that clenching and limitation of jaw opening were significantly related to need for orthodontic treatment. Geering-Gaerny and Rakosi (1971) found in their sample of 281 school children age 8 to 14 that those about to undergo orthodontic treatment had a high prevalence of dysfunction.

Ricketts (1953) used laminagraphic radiography and clinical examinations to study the effects of malocclusion on 190 patients who presented with mandibular dysfunction. The control group consisted of asymptomatic patients, of whom 50 had essentially normal occlusions, 50 had Class II malocclusions, and 15 had Class III malocclusions. He found that "four distinct types of joint disturbance seemed to accrue from four different types of clinical malocclusion." Both balancing side contacts and loss of posterior tooth support were often associated with joint pathology. These findings are in agreement with other studies on occlusion and mandibular dysfunction. However, he also found evidence of pathology in patients with large overjet characterized by Class II Division 1 malocclusion and in those with deep overbites characterized by Class II Division 2 malocclusion. In the former group, the mandible must move forward for incision and speech to compensate for the protruding teeth, but is usually drawn back in forced occlusion. Ricketts theorized that the abnormal range of function stresses the joint and results in condylar trauma. In the latter deep overbite cases, the inclines of the teeth influence the muscles to displace the condyles in a posterior direction. Backwards dislocation of the condyle causes it to lodge behind the disc, leading to clicking or snapping in the TMJ.

As a further evidence for Rickett's theories, Ingervall (1966) found that his sample of 32 patients with Class II Division 1 malocclusion had significantly longer slides from centric relation occlusion to intercuspal position as compared to a control group with Class I occlusion.

Other malocclusions such as functional dental crossbites as a result of a gross occlusal interference, would also be expected to predispose to dysfunction.

A theoretical basis exists for a relationship between malocclusion and dysfunction. The results of epidemiological studies suggest that individuals with malocclusions may in fact have more dysfunction. However, there is a lack of firm evidence for a positive relationship between dysfunction and malocclusion.

d) Development of Mandibular Dysfunction After Orthodontic Treatment

Occlusal malrelationships may develop even after satisfactory orthodontic treatment. This may be due to faulty design of the retainer (Perry, 1976). However, dysfunction may develop as a result of changes which would likely have occurred even without orthodontic treatment. For example, second or third molars, if not erupted at the completion of orthodontic treatment, may erupt in a poor position, causing balancing contacts or functional mandibular shifts, which may in turn predispose to dysfunction. Adverse post-pubertal growth may result in altered occlusal relationships, and hence to dysfunction (Perry, 1976; Thompson, 1956; Roth, 1972).

e) Summary

In conclusion, it is generally agreed that signs and symptoms of jaw dysfunction may develop after orthodontic treatment. Since mandibular dysfunction is not an uncommon occurrence in the untreated pre-orthodontic age group (generally ages 12-18) it is difficult to say whether or not post-treatment dysfunction is a result of the orthodontic treatment per se. There is a possibility that some malocclusions predispose an individual to dysfunction. Incipient dysfunction of the TMJ and associated muscles may begin prior to treatment while the patient is asymptomatic (Williamson, 1976). The orthodontic treatment may make these predisposing factors more or less likely to express themselves, or it may have no effect.

It is possible orthodontic treatment may lead to pathological changes in the TMJ and supporting structures, but, at present, there is no evidence to show that these changes occur.

The majority of investigators feel that much post-treatment dysfunction is a result of occlusal discrepancies. These discrepancies may be a direct result of the orthodontic treatment, or they may be due to other factors which took place after the completion of treatment. Such factors may be the eruption of second or third molars, or late mandibular growth.

Hence, a history of previous orthodontic treatment may be an incidental finding, rather than a factor predisposing to dysfunction.

Underlying the assumptions about orthodontically-related TMJ dysfunction is lack of knowledge of the incidence of dysfunction in post-orthodontic patients as compared to a comparable untreated group. Before the theories on orthodontically-induced dysfunctions can be adequately tested, it must first be shown whether in fact there is a difference in incidence of dysfunction between these two groups. To date there has been a serious lack of documentation in the entire area of orthodontic treatment and mandibular dysfunction.

Surveys of Dysfunction of the Masticatory System

In order to evaluate mandibular dysfunction in the post-orthodontic patient, it is important to know the incidence of signs and symptoms of dysfunction both in symptomatic patients seeking treatment and in the general population at large. Increasing awareness of the incidence of jaw dysfunction in the patient population has led to investigations of the signs, symptoms, etiology and prevalence of the dysfunction. These investigations have been carried out on symptomatic patients seeking treatment, on certain sample groups within the general population, and on complete population groups. Though most examinations have been done on adults, some have involved children as part of the large group, and a few have restricted themselves entirely to children.

a) Surveys on Symptomatic Patients

i. Age

The age distribution of patients seeking treatment for mandibular dysfunction varies between the different studies.

The youngest age reported is 10 and the oldest over 80. The age of patients in most studies falls between the late teens and age 40 (Hankey, 1956; Schwartz and Cobin, 1957; Thomson, 1959; Franks, 1964; Kruse, 1965; Carraro et al., 1969; Butler et al., 1975; Heloe and Heloe, 1975; Carlsson et al., 1976). Tadaka et al. (1971) found the age distribution to be somewhat younger, at 15 to 30. In some studies, an older age group predominated. Zarb and Thompson (1975) stated the mean age in their sample as 41 for males and 36 for females. The dominant age range in the study by Gelb et al. (1967) was 30-60, and ages 40-50 in the study of Perry (1968). Agerberg et al. (1970) found a markedly older age group, 50-74, and Carlsson and Svardstrom (1971) noted that the 20-50 year group predominated.

ii. Sex Distribution

All studies of clinical patients show that the vast majority of these patients are female. The female:male ratio varies from 3:1 to 9:1. The reason why more females than males seek treatment for mandibular dysfunction remains obscure. Although psychological factors may be involved, Smith (1976) felt that psychological studies are inconclusive in that females have not been shown to be more neurotic or anxious than males. He does believe, however, that females have a different "illness behavior" than males. Females, he claims, attend doctors more often than males, because of problems such as premenstrual tension, and thus experience more opportunities to be diagnosed, and are then referred more often for their complaints.

It is important to note that the high ratio of females to males applies only to patients who seek treatment for dysfunction. In studies of randomly selected groups, the female:male ratio is close to 1:1. These studies are discussed later in the review.

b) Studies of Non-Clinical Material

Not all individuals with signs and symptoms of mandibular dysfunction seek treatment. Thus, while clinical studies reveal the characteristics of patients who do seek treatment for mandibular dysfunction, they do not indicate the incidence and nature of mandibular dysfunction in the general population. However, some investigations have been carried out on selected populations of individuals and these studies thus more likely reflect the true picture of mandibular dysfunction in the general population.

i. Early Studies

Brussel (1949) examined two groups consisting of 76 and 85 dental students. He found that 63% and 57% respectively had "two or more clinical progressive symptoms involving the TMJ."

Markowitz and Gerry (1949) examined 700 males at a naval hospital, 50% of whom were age 19 to 30. They stated that 28% had either signs or symptoms of dysfunction. About 12% had a history of pain. The most common symptom was clicking and crepitus which was noted in 16% of the group. Six percent of the group had previously sought treatment.

On examining 2,218 students, Rantanen (1954) found 24% had TMJ sounds or other signs of mandibular dysfunction, involvement in females being almost twice that of males.

These early studies are important in that they were carried out in selected populations, rather than on clinical subjects. They thus give some indication of the incidence of dysfunction in the general population. However, the results of these studies may be somewhat questionable, as "neither the definitions nor the examination methods used in these studies meet modern requirements of epidemiological investigations of functional disorders of the masticatory system" (Helkimo, 1979).

ii. Methodology of More Recent Investigations

The results of more recent investigations are easier to compare and interpret. In most cases, the examination consists of two parts--the first, the elucidation of subjective symptoms by the subject (anamnestic examination) and secondly, the evaluation of objective signs (clinical examination).

In the majority of studies, the anamnestic exam is carried out by oral questions posed by the examiner. Some studies, however, have used a written questionnaire (Agerberg and Carlsson, 1972; Ingervall 1974; Hanson and Nilner, 1975; Molin et al., 1976; Solberg et al., 1979). Written questionnaires have not been used in dysfunction studies involving children.

Because there seems to be general agreement on the "cardinal" signs and symptoms of mandibular dysfunction, the majority of anamnestic examinations pose the same key questions: does the subject experience any subjective symptoms of pain in the region of the jaws and in front of the ears; are there joint sounds on jaw movement; is there limitation of jaw movement; and is there abnormal jaw movement, i.e. subluxation or dislocation? Because other factors are often found in association with the previous four factors, subjects are sometimes questioned about stiffness or tiredness of the jaw, frequent headaches, earache, general joint and muscle symptoms, parafunction (i.e. bruxism and clenching), and a history of arthritis, trauma to the jaws, and psychological problems.

The clinical examination almost always consists of palpation of muscles of mastication and other muscles of the head and neck, palpation of the TMJ, evaluation of joint sounds with or without a stethoscope, measurement of maximum jaw opening, pain on jaw movements and abnormal jaw movements. Deviation on jaw opening is sometimes noted. Amount and direction of slides in centric and balancing interferences on lateral excursions are recorded. The number of missing teeth, balancing interferences on jaw protrusion, overclosure, overjet, overbite, and wear facets may also be noted.

In short, the dysfunction evaluation often consists of two parts.

First, the part pertaining to the presence of the dysfunction itself (e.g. muscle and joint pain, limitation of jaw movement) and second, those factors which may be involved in the etiology of the dysfunction (e.g. occlusal factors such as balancing contacts, trauma, psychological factors).

iii. More Recent Studies on Selected Populations

During examinations of 1240 patients over the age of 15 in a rural dental practice, Zietz (1968) found that about half had headaches, joint sounds, pain in the masticatory muscles, or occlusal discrepancies. Twenty-seven percent reported parafunction habits (grinding and clenching) and 10% experienced reduced mandibular mobility. Females had a higher incidence of headaches, clicking and crepitus.

Posselt (1971) examined 269 dental nurses of ages 19 to 22 for mandibular dysfunction. Few had missing teeth. The most frequent symptom was joint sounds, mainly clicking, which was found in 41% of the subjects. Headache was experienced by 15%. Vertigo and nasopharyngeal symptoms, such as burning throat or tongue, though considered peripheral to modern assessment of TMJ dysfunction (Laskin, 1969) was experienced by 6%. The remaining signs and symptoms in decreasing frequency were pain on movement, limitation of movement, neuralgia, ear symptoms (such as pain or tinnitis), subluxation or dislocation, and tenderness to muscles on palpation. Bruxism was reported by 65%.

iv. Recent Studies on Non-Selected Populations

Agerberg and Carlsson (1973) evaluated a questionnaire answered by 1106 of 1215 randomly selected persons in a Swedish urban population. Joint sounds were the most common symptom and were reported by 57% of those surveyed. Other complaints in decreasing frequency were head and face pain, pain on mandibular movement, and impaired mandibular mobility. Over 50% engaged in oral parafunction activities, which correlated with functional pain. Poor general state of health and general joint and muscle symptoms were closely correlated with impaired mandibular mobility. "The findings suggest that symptoms of functional disorders of the masticatory system are common and that they are of heterogenous aetiological background."

In this study, females reported some symptoms more often than males, but the difference was never greater than 12%, far less a difference than reported in any clinical study. Furthermore, although the 15-24 year age group reported more parafunction and pain on mandibular movement, the differences between age groups were slight, also differing from the findings of most clinical studies.

In a study by oral and clinical examination of two complete populations totalling 321 Lapps, Helkimo (1974 IV) also found roughly the same prevalence of dysfunction between males and females, although some symptoms occur more often in one or the other sex. Dysfunction was also largely the same among the various age groups studies (ages 15 to 75), although the youngest group had the least prevalence of masticatory muscle tenderness on palpation.

In the anamnestic examination (Helkimo, 1974 I) the most common symptom was joint sounds, followed by jaw fatigue and headache. Facial pain, locking and luxation, and movement pain was reported by less than 16%. General joint and muscle symptoms and parafunction were common. During the clinical examination 66% experienced pain on palpation of masticatory muscles; almost half had joint sounds. Deviation and pain on mandibular movement were common findings. The state of the dentition in general was poor, with many missing teeth. "No predominant etiological factor of dysfunction of the masticatory system has been found in the populations studied" (Helkimo, 1976).

Hanson and Nilner (1975) examined a random group of 1069 employees in a Swedish shipyard. Most were between the ages of 20 and 70 and the large majority were males. As in most other studies, the anamnestic examination revealed less dysfunction than did the clinical examination. The latter showed that clicking occurred in 65% of the subjects, tenderness of masticatory muscles in 37%, and joint tenderness in 10%. Thirty percent had two or more of these symptoms. It was estimated that 25-30% of those examined were in need of treatment.

Two studies of male inductees in the Swedish army (average age 19) revealed a much lower incidence of dysfunction than in most other studies of selected populations. Using a questionnaire to gather data, Ingervall and Hedegard (1974) reported that 2.5% of the 287 inductees had limitation of jaw opening and less than 1% had soreness of the masticatory muscles on opening. Those reporting more frequent headaches and clenching were found to be less emotionally stable according to psychological testing. Molin et al. (1976) studied 253 inductees using a questionnaire and a clinical examination. Fourteen percent were aware of TMJ clicking and 12% of other symptoms such as limitation or pain on opening. In the clinical investigation, 28% had some type of dysfunction consisting of tenderness of masticatory muscles or TMJ to palpation as well as difficult, painful, or irregular mandibular movements. Those with dysfunction had a higher frequency of general joint and muscle symptoms.

The low incidence of dysfunction in army inductees as compared to other groups is noteable. It can be assumed that a group of young men in the armed forces would have good general health. Poor health appears to correlate with a greater dysfunction (Berry, 1969). Furthermore, the dentitions in these two groups were intact and in a reasonable state of repair. In contrast, the Lapps in Helkimo's (1974 III) study had a very high incidence of dysfunction and a poor state of dental health, with multiple missing teeth.

Wigdorowicz-Makowerowa et al. (1979) examined 429 medical students, 400 military students, 1000 soldiers age 20-23, 1000 age 39-45, and 2100 schoolchildren. The last group will be discussed under "Studies on Children." The diagnosis of mandibular dysfunction was made by the presence of one or more of pain in the area of the TMJ, crepitus, irregular jaw movements or subluxation of the condyles. The medical students had the highest incidence of dysfunction, 57%, followed by 49% for the military students, 44.5% for the older soldiers and 36.4% for the younger soldiers. Of those with symptoms, the incidence of pain was the highest for the medical students at 75% and lowest for the older soldiers at 40%. Dysfunction was 1.5 times as high for those with bruxism. Bruxism was twice as high for those under psychologic tension.

A sample of 739 university students ages 19 to 25 were examined by Solberg et al. (1979). As in other studies, clinical signs of dysfunction occurred more frequently than awareness of symptoms. Twenty-five percent of the sample were aware of symptoms, yet 58% of females and 46% of males exhibited clinical signs of dysfunction. Headaches were reported by 12.5%. Joint sounds, facial pain and pain on chewing occurred in decreasing frequency. Only headaches occurred significantly more often in females. The clinical examination revealed that pain on palpation of masticatory muscles occurred in almost one-half of the subjects, clicking in one-third, and limited opening in 3.5%. Females had higher incidences of the first 2 of the 3 signs. Twice as many men were free of signs and symptoms of dysfunction as were women.

c) Socio-Economic Factors

The higher socio-economic groups appear to be over-represented in clinical subjects with mandibular dysfunction (Reider, 1976; Nally & Moore, 1975; Heloe & Heloe, 1975; Butler et al., 1975; Franks, 1964). However, the best authority on the relationship between socio-economic class and dysfunction in the general population is a study in a random sample questionnaire of 1106 persons from ages 15 to 74 by Agerberg et al. (1977). They found that symptoms occurred somewhat less frequently in the higher socio-economic group. "This epidemiological study indicates that the overrepresentation of patients from upper social strata in clinical series probably is due to the fact that people with higher education tend to seek advice for their symptoms of mandibular dysfunction more than those with lower education."

d) Summary

Clinical surveys elucidate the incidence of signs and symptoms of mandibular dysfunction in symptomatic patients who seek treatment. Since most symptomatic individuals do not seek treatment, studies on population groups provide valuable data on mandibular dysfunction in the population at large.

There are some general conclusions which can be drawn from the aforementioned general population studies:

1. The incidence of mandibular dysfunction is about the same in

males and females, or at most, slightly higher in females.

2. The prevalence of dysfunction does not differ greatly among the age groups from adolescence to old age.
3. Clinical signs of dysfunction occur more frequently than awareness of subjective symptoms.
4. Joint sounds, mostly clicking, is the most common sign, followed by muscle tenderness on palpation.
5. Facial pain, TMJ pain, and limitation of opening occur with less frequency.
6. Headaches and general joint and muscle symptoms commonly accompany mandibular dysfunction.
7. Socio-economic factors do not seem to be significant in the epidemiology of mandibular dysfunction.

Studies on Children

Geering-Gaerny and Rakosi (1971) examined 281 school children age 8 to 14. They reported that 41% had one or more of joint sounds, pain on palpation of masticatory muscles or TMJ, deviation of mandible from the midline on opening, and condylar subluxation.

Uzhumutskene (1974) examined 1000 children aged 1 to 16 and found that 13.4% had symptoms of "arthropy" of the TMJ.

Lindqvist (1974) examined 117 pairs of twins and found that 27% had tenderness of the lateral pterygoid or masseter muscle to palpation.

Karolakowska and Starzynska (1974) performed an epidemiological study on 200 children aged 7 to 14 and 100 aged 13 to 15. They found that 27% and 33% respectively showed evidence of TMJ disturbances. In the older group, those with malocclusions and parafunction habits had a slightly higher incidence of dysfunction, though not of statistical significance.

A study was undertaken by Grosfeld & Czarnecka (1977) to determine the incidence of mandibular dysfunction in 500 children, half of which were 6-8 years of age and the other half 13-15. They classified "minor" symptoms as consisting of deviation of the mandible during opening, asymmetric condylar movements, and TMJ clicking. Major symptoms include crepitus, restriction of mandibular opening, pain in the TMJ region and abnormal mandibular morphology. They found in the 6-8 year group that 36% had minor symptoms and 20% major symptoms. There was a statistically significant increase in symptoms in the 13-15 year group, where 34% had minor symptoms and 34% had major symptoms.

As part of their larger study, Wigdorowicz-Makowerowa et al. (1979) examined 2100 children aged 10-15. At 16%, this group had the lowest incidence of dysfunction in comparison to the older group studied. Of those with dysfunction, 16% experienced pain.

Although very few children seek or receive treatment for mandibular dysfunction, it is not an uncommon phenomenon in the child population. Joint clicking is by far the most common sign, followed by muscle tenderness on palpation, and mandibular deviation on opening. Other signs occur only infrequently. The relationship between occlusion and dysfunction is obscure. Sex differentiation in prevalence of the disorder is unknown. Incidence of dysfunction may increase with age from early to late teens. Although there appears to be parallels between adult and childhood dysfunction, little is actually known about the latter.

Mandibular Dysfunction and Occlusion

Occlusion may be viewed in different ways. The orthodontist traditionally has seen occlusion as the static relationship among the teeth within the dental arches. Malocclusion is viewed as both a dentofacial deformity and as a malalignment of the teeth. With the teeth in contact in centric occlusion, the occlusion may be classified according to molar and cuspid relationship, overjet and overbite, crowding, crossbites, and other factors. The occlusion is usually evaluated according to the static relationship of the teeth. In most other disciplines of dentistry, however, "occlusion" expresses a dynamic relationship of the opposing teeth during mandibular movements, as well as their static interrelationship. The emphasis is on function, rather than on aesthetics. This latter definition of "occlusion" is the one used in almost all studies of the relationship between mandibular dysfunction and occlusion, and is the one which is used in the following discussion.

Because clinical empiricism suggests a relationship between malocclusion and mandibular dysfunction, most studies of dysfunction involve an occlusal evaluation. Missing teeth are considered to be an aspect of malocclusion.

a) Missing Teeth

Both a clinical study (Franks, 1967) and an epidemiological study (Helkimo, 1974 III) have demonstrated a positive relationship between missing teeth and mandibular dysfunction in adults. In children, those who have lost primary teeth and do not yet have some permanent teeth in occlusion have more dysfunction symptoms (Geering-Gaerny and Rakosi, 1971). Agerberg and Carlsson (1973, 1975) found that although there was no significant difference in average numbers of missing teeth between those who sought treatment and a random population group, in the latter group subjective appraisal of impaired mandibular mobility increased with the number of teeth lost. Brussel (1949) after studying both patients with jaw dysfunction and selected populations of adults and university students summed up quite well, with admirable foresight, the present view: "malocclusions or multiple tooth loss are apparently of a contributory and not a primary cause" of TMJ dysfunctions.

b) Occlusal Discrepancies

Empirical clinical evidence has shown that many cases of mandibular dysfunction are cured or improved by accurate occlusal equilibration (Thomson, 1959; Ramfjord, 1961; Roth, 1973; Dawson, 1976). The purpose of the equilibration is to harmonize tooth position with the position and movements of the TMJ. In theory, this harmonization should require the least amount of neuromuscular adaptation by the patient (Ramfjord and Ash, 1971). Clinical evidence indicates that an occlusion created in this manner is well tolerated by the majority of patients (Roth, 1972).

The equilibration procedure involves bringing the maximum number of teeth into contact in IP, elimination of slides between RCP and IP, and elimination of balancing and protrusive interferences. Markowitz and Gerry (1949) and Posselt (1971) observed that in their samples of population groups, those with dysfunction were often helped by occlusal equilibration.

In spite of these findings, there does not appear to be a consistent relationship between occlusal discrepancies and mandibular dysfunction. Some investigators have found more balancing side contacts in individuals with dysfunction (Posselt, 1963; Solberg et al., 1972; Molin et al., 1976; Barghi, 1978). Barghi (1978) and Solberg et al. (1979) found that asymmetric slides from RCP to IP correlated with increased dysfunction. However, in a significant number of studies, there was found no relationship between occlusal discrepancies and dysfunction (Loiselle, 1969; Helkimo, 1974 III; Butler et al., 1975; Heloe and Heloe, 1975). Furthermore, balancing contacts are a common phenomenon in individuals with no signs of dysfunction (Ingervall, 1972). Anterior slides from RCP to IP exist in the vast majority of asymptomatic individuals as well (Barghi, 1978; Solberg et al., 1979).

In spite of the lack of a clear association between occlusal discrepancies and mandibular dysfunction, some patients obtain relief from dysfunction signs and symptoms by removal of balancing contacts and/or slides in centric. Apparently, then, it is not the occlusion per se which may lead to dysfunction but rather the response of each individual to his particular occlusion. This response is moderated by emotional and other factors. Occlusion should be seen, then, as not the sole cause, but rather a contributing factor to mandibular dysfunction.

Indexing Malocclusion

Because a malocclusion is really the sum of many different factors, and because each factor is of different importance, it is convenient to evaluate malocclusions in terms of an index. An index is of particular use in surveys, where large numbers of individuals, or changes within individuals, can be more easily compared. If standardized indices are adopted, the results of varying studies may be more easily compared.

a) Index for Studies of Functional Malocclusion

Indices have been little used for classifying functional malocclusions in studies of mandibular dysfunction. Helkimo (1974 II) has designed such an index. The factors measured are those which were found to be associated with dysfunction in one or more surveys of mandibular dysfunction. These factors and their associated indices are:

1 - number of missing teeth and teeth in occlusion--Occlusal Index

2 - lateral and anterior centric slides--Centric Slide Index

3 - balancing side contacts and unusual lateral guidance--Articulation Interference Index.

b) Other Malocclusion Indices

Malocclusion, from the orthodontic viewpoint, is a dentofacial abnormality which compromises a person's physical or emotional health. Malocclusions may cause difficulties in eating or speaking and may lead to damage of periodontal tissues. Of equal, if not greater importance, malocclusion may be sufficiently disfiguring as to negatively affect self-image and self-esteem.

There is some agreement on what constitutes an "ideal" occlusion, but this type of occlusion occurs only in 1 or 2% of the population, according to the National Research Council Committee on Handicapping Orthodontic Conditions (1976). However, there is no comprehensive definition of "normal" occlusion (Moorrees et al., 1971). Hence, the term "malocclusion" also remains ill defined. The subjective assessment of the examiner is a major factor in assessing the existence or severity of malocclusion.

A number of indices have been devised to deal with the problem of malocclusion assessment. These indices have been used in two major ways--to determine the prevalence of malocclusion in a particular group, and to establish priorities for orthodontic treatment. They are designed to be used by the non-specialist.

The indices which have received the most attention to date are the Handicapping Labio-Lingual Deviations (HLD) (Draker, 1958), the Index for the Assessment of Handicapping Malocclusion (Saltzmann, 1970), the Occlusal Index (Summers, 1971) and the Treatment Priority Index (TPI) (Grainger, 1967).

The TPI is the most comprehensive index and has been the most widely used (Committee on Handicapping Orthodontic Conditions, 1976). It is based on the concept that malocclusion is not one simple condition, but rather a series of distinct, but related conditions. Using regression analysis to determine weighting factors for these conditions, a single TPI score is determined for each individual. The TPI score indicates the need for orthodontic treatment.

Although the TPI has not been shown to have overall biologic validity (Committee on Handicapping Orthodontic Conditions, 1976), it has been shown to have a close correlation with the assessment of malocclusions by orthodontists (Popovich and Thompson, 1971; Scivier et al., 1974).

Indexing Mandibular Dysfunction

Comparisons between studies of mandibular dysfunction have been made difficult by lack of agreement on the definition and evaluation of dysfunction. An index would be useful for evaluating the prevalence and course of the signs and symptoms of dysfunction.

Helkimo (1974 II) has designed two indices for the evaluation of mandibular dysfunction. The Anamnestic Dysfunction Index (ADI) is calculated from the patient history (anamnestic examination). The Clinical Dysfunction Index (CDI) is calculated from the clinical examination. In the calculation of the indices, the more severe symptoms and signs of mandibular dysfunction are assigned high values in comparison to mild symptoms and signs of dysfunction. A single ADI and CDI score is then determined for each individual.

Helkimo's Dysfunction Indices have been shown to have some credibility in a recent study by Helkimo et al. (1979) on the electromyographic silent period of 58 patients with mandibular dysfunction. Previous evidence has shown that the silent period is longer in patients with signs and symptoms of dysfunction (Bessette et al., 1971; Bailey et al., 1977). This investigation found there was significant correlations between certain variables of the dysfunction indices and the duration of the silent period.

Summary

Both clinicians and researchers have shown a keen interest in investigating dysfunctions of the masticatory system. Most recent studies on random samples of non-clinical subjects have shown that mandibular dysfunction is more widespread than previously believed and that there is no great difference in incidence between the sexes and among the various age groups. Because of differing results among the studies, there is little agreement on the effects of functional occlusal discrepancies on mandibular dysfunction. The relationship of static malocclusion and dysfunction has been little examined and requires further clarification. Of particular importance is the lack of data on the relationship of orthodontic treatment and mandibular dysfunction. This research was conceived with the intent of furthering knowledge in these uncertain areas.

METHODOLOGY

This study was designed to gather and analyse data to relate malocclusion and mandibular dysfunction. The sample was composed of 371 individuals between the ages of 12 and 30.

The actual survey was preceded by a pilot study of 26 individuals who had completed orthodontic treatment at the University of Manitoba. The purpose of this pilot study was to determine the feasibility of the examination methods, the time required per examination, and the suitability of the designed examination forms.

The pilot study revealed that the proposed examination method was feasible, and that each examination would require 12 to 15 minutes. On evaluation of the pilot study data, the recording forms were altered to make the examinations more comprehensive and to rationalize the gathering of the data.

The Sample

The populations sampled were divided into two main groups--those who had received orthodontic treatment (treated group), and those who had not received orthodontic treatment (control group).

a) Treated Group

This group was comprised of individuals who had undergone orthodontic treatment with multiband appliances or functional appliances. Only those who had completed active treatment at least six months previously were selected for examination in order to allow some "settling in" of the occlusion and to allow the effects of appliances and elastics on the musculature to dissipate. However, some were still wearing retainers at the time of examination.

The treated group is composed of three sub-groups. These sub-groups are characterized as follows:

T-CLINIC 137 persons treated at the University of Manitoba Graduate Orthodontic Clinic. They were examined while they appeared for routine post-treatment assessment. This assessment period lasted about four years after debanding. This number comprised 81% of all eligible subjects.

T-HS1 16 students examined at Grant Park High School in Winnipeg. This school will be referred to as High School 1.

T-UofW 17 general arts and science students examined at the University of Winnipeg.

b) Control Group

This group was comprised of four subgroups of individuals who had not had orthodontic treatment.

C-CLINIC 62 persons who had sought treatment for malocclusion at the University of Manitoba Graduate Orthodontic Clinic.

C-HS1 52 students from High School 1.

C-HS2 52 students from Gordon Bell High School. This school will be referred to as High School 2.

C-UofW 35 general arts and science students from the University of Winnipeg.

The distribution of the sample by subgroup, age and sex is shown in Table I.

Table I

Distribution of the sample of 371 individuals by group, subgroup, age and sex

	Mean Age (Years)	Male	Female	Total
Treated Group				
T-CLINIC	18.2	38	99	137
T-HS1	16.1	5	11	16
T-UofW	20.3	6	11	17
Subtotal		49	121	170
Control Group				
C-CLINIC	16.8	20	42	62
C-HS1	15.1	18	34	52
C-HS2	17.8	23	29	52
C-UofW	20.7	14	21	35
Subtotal		75	126	201
Total		124	247	371

c) Selection of Subjects

The subjects comprising the control group were selected to match as accurately as possible the age and sex distribution of the treated group. Minor differences in this distribution were assumed to be unimportant as previous studies have shown that dysfunction does not vary greatly between sexes and among the various age groups.

The method of choosing subgroups in the high schools was as follows: the schools were chosen on the basis of their large student population. High School 1 was in a middle class area of the city, and High School 2 in a working class area. Classes were selected for surveying in a way that would reflect the general student population from Grade 7 to 12. In High School 1, 375 consent forms were distributed among 12 classrooms. The positive replies numbered 89 and 66 students were ultimately examined. Of the total seen, 10 had received previous orthodontic treatment and 56 were untreated.

In High School 2, 280 consent forms were distributed among 10 classes. The positive replies numbered 71 and 52 students were ultimately examined. None of these had received previous orthodontic treatment.

At the University of Winnipeg, volunteers were solicited from 7 classes. Of the 52 individuals who underwent examination, 17 had had previous treatment, and 35 had not.

d) <u>Bias in Selection</u>

Every effort was made to eliminate bias in selection of subjects for examination. Because some explanation of the methods and purposes of the survey had to be given to prospective subjects, those with dysfunction symptoms may have been more willing to volunteer. If so, then the surveyed sample would not have been representative of the general population for the incidence of mandibular dysfunction.

This potential problem did not arise for sub-groups T-CLINIC and C-CLINIC as all who were asked agreed to participate in the study. Several individuals in C-CLINIC were considered ineligible for examination because they had sought orthodontic treatment specifically for alleviation of dysfunction symptoms.

In the high schools surveyed, all the students within a selected class were given a consent form. Those under the age of 18 years were required to have the form signed by a parent or guardian. The consent form used is shwon in Appendix Table I. In this form the exact purpose of the survey was left somewhat vague to avoid attracting subjects seeking help for dysfunction problems.

The University students were visited in their classes and asked to participate. A short verbal description of the purpose of the research was given. Once again, the exact purpose of the study was left somewhat vague in order to minimize bias of the subject.

Duration of Survey

The actual survey was conducted from November 1978 to January 1980. The examinations took place over a considerable time period as there were delays in arranging access to the high schools and the University. The examinations in the high schools took place in the spring of 1979. The University students were examined in January of 1980. The bulk of the subgroup seeking orthodontic treatment were examined in December 1978 and December 1979. The examinations for the University of Manitoba treated group took place over the entire length of the survey. Thus, if there were inadvertent changes in the examination technique, the changes would have taken place for both the treated and control groups.

Method of Examination

In order to maintain consistency of methodology, the questions for the anamnestic examination were written down so that they could be asked in the same way for all examinations. By following the order of the clinical examination form, the clinical examination was done in the same way for each subject. None of the results were analysed until all the examinations were complete, in order to prevent the examiner from developing a particular bias.

The equipment used consisted of mouth mirrors, pencils, rulers, and cellulose strips. Examinations outside the confines of the Faculty of Dentistry required the use of a portable chair, light and stool.

The form used in gathering the data for the anamnestic examination is shown in Appendix Table II, and the corresponding explanation in Appendix Table III. The clinical examination form is shown in Appendix Table IV and the corresponding explanation in Appendix Table V.

A brief explanation of the examination methodology follows.

a) Anamnestic Examination

The subjects were asked if they experienced headaches at least twice a week, pain in the area of the TMJ and ears, face, temple, neck, back, body joints, and pain on mandibular movement. If any of the symptoms were present, the subjects were asked about duration and etiology. A notation was made if the etiology of a pain symptom was likely related to factors other than those of mandibular dysfunction. Such etiological factors (e.g. pulpitis or pericoronitis) are referred to as "predisposing causes" (P.C.).

The subjects were also asked about a history of bruxism, jaw fatigue, limited mandibular opening, subluxation or dislocation of the mandible, TMJ sounds, trauma to the jaws, and previous treatment for dysfunction symptoms.

b) Clinical Examination

The clinical examination consisted first of palpation of posterior neck muscles, muscles of mastication, and the TMJs. The mouth was examined for missing, rotated and displaced teeth. The number of restored posterior tooth surfaces was noted. The occlusion was evaluated for crossbites, overjet, overbite, molar relationship, cuspid relationship, and dorsal locking (deep overbite with less than one mm. overjet). Measurements were made of maximum mandibular protrusion, maximum lateral movements, and maximum opening, as well as deviations on opening and jerky jaw movements. Any pain experienced during these movements was noted. Centric slides from RCP to IP were measured in length and direction, as was the type of guidance--cuspid guidance, group function, or other guidance such as guidance by one posterior tooth. Notations were made of subluxation (partial jaw dislocation easily reduced by the subject), or dislocation (total jaw dislocation reduced with great difficulty). A stethoscope was used to evaluate TMJ clicking and crepitus.

A subjective assessment of the malocclusion (SAM) was recorded by the examiner according to the following code:

SAM-1 no orthodontic treatment required

SAM-2 moderate malocclusion; treatment optional

SAM-3 severe malocclusion; treatment mandatory.

A subjective assessment of the state of dysfunction (SAD) was recorded by the examiner according to the following code:

SAD-1 no dysfunction, or clicking as the only dysfunction sign

SAD-2 moderate dysfunction; adequate ability to function possible

SAD-3 severe dysfunction; normal functioning not possible.

Assessment of the Data by Cardinal Symptoms and Signs

The majority of the variables recorded in this study pertain to mandibular dysfunction. In assessing the incidence of dysfunction, each component variable could be assessed individually. However, it is more convenient to group related variables under major headings. Such variables were grouped under the cardinal symptoms and signs of mandibular dysfunction. The term "symptoms" pertains to information from the anamnestic examination, while "signs" pertains to information from the clinical examination. The three cardinal symptoms and signs are joint sounds, pain, and limitation of mandibular movement. Subluxation and dislocation are included with limitation of mandibular movement. This grouping was carried out for both the anamnestic (oral) examination and the clinical examination, and is shown in Table II. The criteria for the determination of limitation of mandibular movement in the clinical examination were obtained from Helkimo (1974 II).

Indices Used in Analysis of Data

The indices developed by Helkimo (1974 II) were used as an aid in analysing the data. These indices were altered slightly to facilitate analysis of the data gathered in this particular study.

a) Anamnestic Dysfunction Index

The Anamnestic Dysfunction Index (ADI) is designed to categorize symptoms of dysfunction noted during the oral history. Higher index values indicate increased severity of dysfunction symptoms. The index

Table II

Makeup of the cardinal symptoms and signs of mandibular dysfunction

A. Anamnestic Examination

Cardinal Symptom	Criteria
Joint Sounds	1. TMJ sounds on jaw movement
Pain	1. Pain in the area of the ears and TMJ, face, temple
	2. Pain on jaw movement
Limitation of Movement	1. Limited jaw movement
	2. Subluxation and/or dislocation of TMJ

B. Clinical Examination

Cardinal Sign	Criteria
Joint Sounds	1. Clicking
	2. Crepitus
Pain	1. Pain on palpation of one or more muscles of mastication
	2. Pain on palpation of TMJ
	3. Pain on jaw movement
Limitation of Movement	1. Maximum protrusive and lateral movements < 7 mm.
	*2. Maximum mouth opening < 40 mm.
	3. Subluxation of TMJ
	4. Dislocation of TMJ

*sum of maximum mandibular opening and overbite is scored as follows:

ADI-1 no dysfunction symptoms

ADI-2 jaw sounds and/or a feeling of jaw stiffness or fatigue as the only dysfunction symptoms

ADI-3 any one of: pain on the side of the face, pain in the temple region, pain on jaw movement, limitation of jaw movement, subluxation or dislocation.

As mentioned, pain symptoms may have predisposing causes (P.C.) unrelated to mandibular dysfunction. If P.C. was recorded on the examination form for one of these symptoms, the symptom was not recorded as present. Only if there was no predisposing cause was the symptom recorded as present for the purpose of calculating the Anamnestic Dysfunction Index.

b) Clinical Dysfunction Index

The Clinical Dysfunction Index (CDI) is designed to categorize the signs of dysfunction noted during the clinical examination. The calculation of this index is more complex than the other indices. The detailed method of calculating this index is found in Appendix Table VI. In short, however, the mild signs of dysfunction, if present, are each given one point. These mild signs include slightly impaired range of mandibular mobility, TMJ sounds, deviation of jaw opening, tenderness of 1-3 palpation sites of the masticatory muscles, tenderness to palpation of the lateral aspect of the TMJ, and pain on mandibular movement in one direction. The more severe signs of dysfunction if present are each given 5 points. These more severe signs include severely impaired range of mandibular mobility, subluxation or dislocation of the TMJ, tenderness of 4 or more palpation sites of the masticatory muscles, tenderness to palpation of the posterior aspect of the TMJ, and pain on mandibular movement in two or more directions.

The points for the mild and more severe signs of dysfunction are summed to give a total dysfunction score, and the three CDI groups are determined as follows:

CDI-1 total dysfunction scores of 0 or 1 indicating no dysfunction or very mild dysfunction

CDI-2 total dysfunction scores of 2, 3 or 4, indicating moderate dysfunction

CDI-3 total dysfunction scores of 5 or more indicating more serious dysfunction.

c) Functional Indices

Functional findings derived from the clinical examination were grouped according to two other indices: Centric Slide Index (CSI) and Articulation Interference Index (AII). The CSI was calculated as follows:

CSI-1 no slides between RCP and IP

CSI-2 one or both of:

a) lateral slide 0.5 mm. and anterior slide 0 to 2.0 mm.

b) lateral slide 0 mm. and anterior slide 1.5 or 2.0 mm.

CSI-3 lateral slide greater than 0.5 mm. or anterior slide greater than 2.0 mm.

The A.I.I. was calculated as follows:

AII-1 no balancing side contacts; lateral excursions of the mandible by group guidance or cuspid guidance

AII-2 no balancing side contacts; lateral excursions by an unusual type of guidance (e.g. only the most posterior molar contacts on excursions)

AII-3 balancing side contacts on lateral excursions.

d) Treatment Priority Index

The Treatment Priority Index (TPI) of Grainger (1967) as described in the literature review was used to categorize static malocclusions. The TPI scores are derived from an assessment of 6 occlusion syndromes. These syndromes are the antero-posterior relationship of the first permanent molars, positive or negative overjet, overbite or open bite, rotated and displaced teeth, crossbites, and congenitally missing incisors. The scores obtained are interpreted as follows:

0-3 minor manifestations of malocclusion; treatment needs slight

4-6 definite malocclusion; treatment desirable

7-9 severe handicap; treatment highly desirable

10+ very severe handicap; treatment mandatory.

e) Age Group Indices

For ease of analysis, the sample was divided into three age groups as follows:

Age-1 12-15 years

Age-2 16-19 years

Age-3 20-30 years.

Analysis of Data by Categories

For ease of analysis the data gathered from the examination was divided into four categories: anamnestic examination, clinical examination, occlusal examination, and functional examination (see Table III). Categories 1 and 2 are comprised of data pertaining to the dysfunction

Table III

The four examination categories, their component primary and secondary factors and the associated indices

Primary Factors	*v	Secondary Factors	*v	Index
1) ANAMNESTIC EXAMINATION				
TMJ and ear pain	d	headache	d	ADI
face pain	d	neck pain	d	
movement pain	d	back pain	d	
limitation of movement	d	body joint pain	d	
subluxation/dislocation	d	jaw fatigue	d	
joint sounds	d	history of trauma	d	
		history of previous treatment	d	
2) CLINICAL EXAMINATION				
muscle pain	d	jaw deviation	d	CDI
TMJ pain	d	jerky movements	d	
movement pain	d			
maximum jaw movements	c			
TMJ sounds	d			
subluxation	d			
dislocation	d			
3) OCCLUSAL EXAMINATION				
missing teeth	c	third molar extraction	d	TPI
rotated teeth	c	orthodontic extractions	c	
displaced teeth	c	restored post. surfaces	c	
cross bite	c	dorsal locking	d	
molar/cuspid relationship	d			
overbite	c			
overjet	c			
4) FUNCTIONAL EXAMINATION				
point centric	d			CSI
lateral slides	c			
anterior slides	c			
lateral guidance	d			AII
balancing contacts	d			

*v - type of variable c - continuous d - discrete state; the third category is descriptive for static occlusion and the fourth, descriptive for functional occlusion. The factors which are contained within these categories are divided into primary and secondary.

Primary factors for the anamnestic and clinical examinations are related to the cardinal dysfunction symptoms and signs, while secondary factors are those which are often found in association with dysfunction.

The primary factors in the occlusal examination are those which are used in calculating the TPI Index, while the remaining factors evaluated are classified as secondary.

In the functional examination all factors are considered primary.

Also contained within the four categories are their associated indices. It is notable that most of the data which make up a particular index are derived from information contained within the primary division of the categories.

A special computer program was written to calculate these indices from the raw data. The indices were then added to the data file and further statistical analyses were performed using the computer program as described by Nie et al. (1975).

Statistical Analysis

Statistical analysis was carried out by the Biostatistics Division of the Faculty of Dentistry at the University of Manitoba.

The data in this study contained discrete (d) and continuous (c) variables (see Table V), and the methods of analysis varied accordingly.

a) Discrete Variables

For descriptive purposes there are two types of discrete variables contained in this study. The first type is made up of indices, most of which fit into a 3-category classification (e.g. ADI-1, ADI-2, ADI-3). The second type is made up of variables which fit into a 2-category classification (e.g. the presence or absence of previous orthodontic treatment, headache, or pain on mouth opening). Contingency chi square analysis was used in comparing the various discrete variables to reveal any statistically significant relationship. In the tables of results the various levels of significance were recorded as follows:

N.S.	not significant
*	$p < .05$
**	$p < .01$
***	$p < .001$

where p is the probability of falsely rejecting the null hypothesis.

b) Continuous Variables

Continuous variables are those which lie within a continuous classification. Examples of continuous variables are the number of missing teeth, amount of overjet and amount of maximum mouth opening. Analysis of variance (ANOVA) was used in comparing continuous with discrete variables to reveal statistically significant relationships. For ease of comparison the various indices are sometimes treated as continuous variables. Levels of statistical significance were recorded as described for discrete variables. Where the ANOVA revealed statistical significance of differences among more than two means, the "least significant difference" (Steel and Torrie, 1960), was used to compare selected pairs of means.

RESULTS

Incidence of Mandibular Dysfunction

a) Incidence of Cardinal Symptoms and Signs

It is generally agreed that the cardinal symptoms and signs of mandibular dysfunction are joint sounds, pain and limitation of movement. The incidence of mandibular dysfunction in the entire population studied is most easily assessed by evaluating the incidence of these cardinal symptoms and signs. A cardinal symptom or sign is considered to be present if any one of its component variables is present as shown in the Methodology in Table II.

The distribution of these cardinal symptoms and signs is shown for the anamnestic and clinical examinations in Appendix Table VII. The distribution of the sample by the number of cardinal symptoms in the anamnestic examination and signs found in the clinical examination is found in Figure 1. In the anamnestic examination, 58% reported at least one symptom of dysfunction, while in the clinical examination, one or more dysfunction signs were found in 68% of the subjects. Forty-four percent of the subjects had both symptoms and signs of dysfunction, while 18% had neither dysfunction symptoms nor signs. The presence of three cardinal symptoms and signs, indicating serious dysfunction, was low for both examinations at 5% for the anamnestic examination and 6% for the clinical examination.

The distribution of the types of signs and symptoms is shown in Figure 2. Joint sounds was the most common sign/symptom at 39% for both

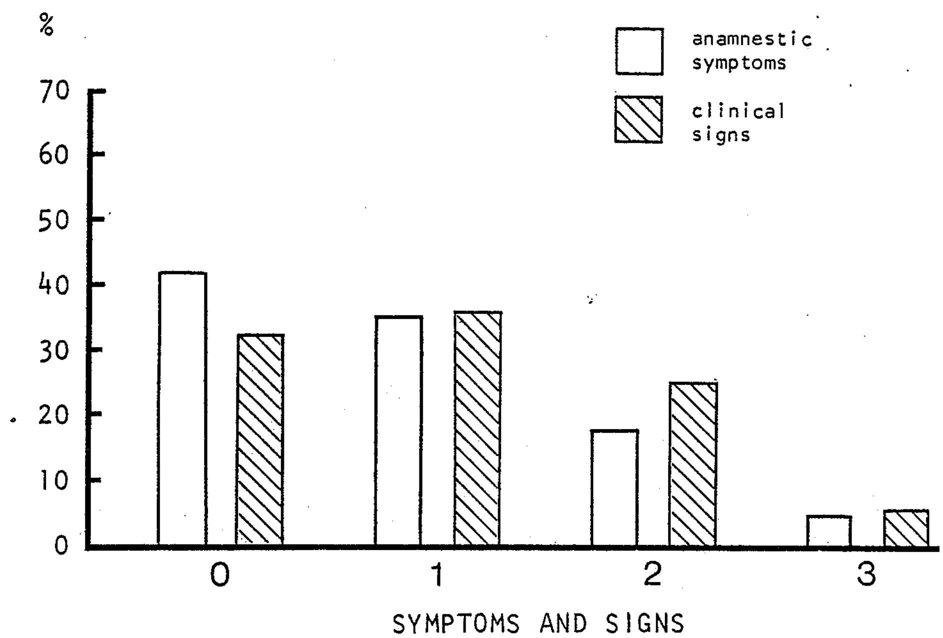

Figure 1. Percentage distribution of the entire sample by the number of cardinal dysfunction symptoms and signs.

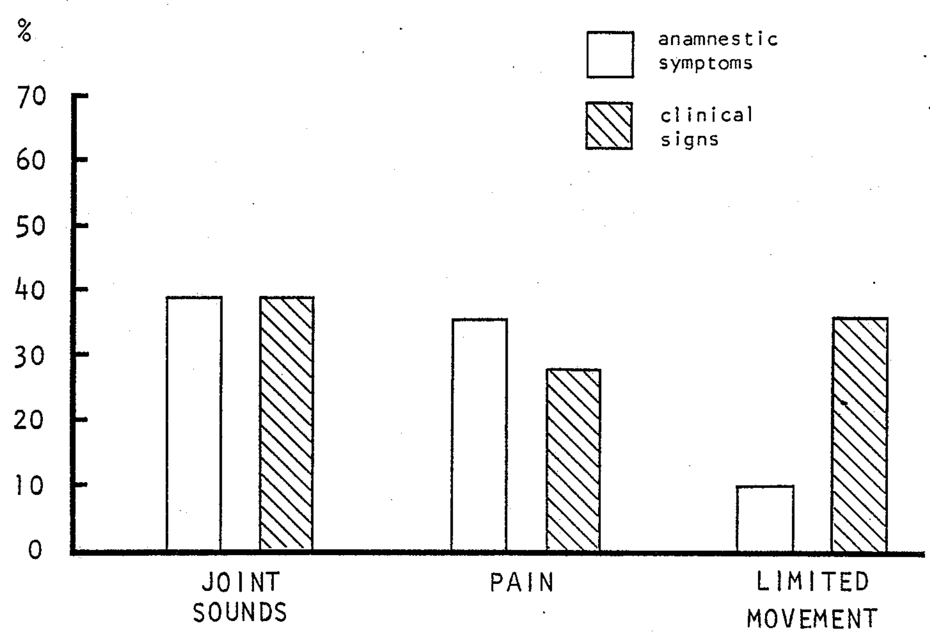

Figure 2. Percentage distribution of the entire sample by the type of cardinal dysfunction symptoms and signs.

examinations. Limitation of movement was much higher in the clinical examination at 37% compared to only 10% in the anamnestic examination.

In general, there is close agreement between clinical and anamnestic examinations in the total number of cardinal signs/symptoms of dysfunction. By far the largest difference is for limitation of movement.

b) Anamnestic Examination

i Predisposing Causes

As described in the Methodology, the cardinal symptom of pain is considered present if any individual pain symptom from the anamnestic examination is present. The pain symptoms and their incidence are listed in Table IV. Listed beside each pain symptom is the incidence of predisposing causes (P.C.) for that symptom. If a symptom is not likely of dysfunction in origin, then the symptom is said to have a predisposing cause. Of those with TMJ and ear pain, 25% had predisposing causes, while the percentages for movement pain, face pain and temple pain were 13%, 20% and 2% respectively.

ii Duration of Symptoms

The subjects were asked about the time of initial onset of any symptoms they reported. The duration of the symptomatic state could then be calculated. The results of this part of the investigation showed that the vast majority of symptomatic subjects could not recall when their symptoms began. Furthermore, most treated subjects could not even remember the onset of their symptoms in relation to the time of their orthodontic treatment. Because of poor reliability, it was therefore decided to omit duration of symptoms from further

Table IV

Incidence and percentage distribution of pain symptoms found in the anamnestic examination and incidence and percentage distribution of corresponding predisposing causes

	Incidence		Predisposing causes	
Symptom	Number (n=371)	Percent	Number	Percent
TMJ and ear pain	65	17.5	16	24.6
Movement pain	51	13.7	10	19.6
Face pain	46	12.4	6	13.0
Temple pain	48	12.9	1	2.1

Table V

Incidence and percentage distribution of associated dysfunction factors in the anamnestic examination

Factor	Number (n=371)	Percent
Headache	84	23
Neck pain	130	35
Back pain	107	29
Body joint pain	44	12
Bruxism	81	22
Trauma history	40	11
Previous treatment	3	1

consideration in this investigation.

iii Associated Dysfunction Factors

Associated dysfunction factors are those which are often found in association with mandibular dysfunction. The incidence of these factors is shown in Table V. A history of stiff or sore neck, back pain, and frequent headache (at least twice a week) were very common and reported respectively by 35%, 29% and 23% of the population. Twelve percent reported a history of stiff or swollen body joints, while 22% reported a history of bruxism or clenching, and 11% reported a history of trauma to the jaws.

Only three subjects had sought treatment for dysfunction symptoms, and they were part of the control group.

c) Clinical Examination

i Primary and Secondary Dysfunction Factors

Because of the importance of the clinical examination, the incidence of the individual variables is discussed in more detail and is shown in Appendix Table VIII.

The muscle most often sensitive to palpation was the lateral pterygoid, in 14% of the subjects examined. The TMJ was sensitive to lateral and posterior palpation respectively in 6% and 4% of the subjects. Pain on any single jaw movement occurred in less than 5% of the subjects. Clicking was the most common dysfunction sign occurring in 32%, while crepitus was found in 10% of the subjects. Subluxation was found in only four individuals and dislocation was not observed.

Both jaw deviation and jerky jaw movements occurred in 12% of the subjects.

Comparison of Dysfunction and Occlusal Factors for Control and Treated Groups

The prime purpose of this study is to compare the incidence of mandibular dysfunction between control and treated groups. A second important purpose is to examine the relationship between occlusal variables and the signs and symptoms of dysfunction. This subsection deals with these purposes.

a) Anamnestic Examination

i Cardinal Symptoms

The difference in incidence of the cardinal symptoms between the control and treated group is shown in Figure 3. The control group had a higher incidence of history of pain ($p < .001$) and limitation of movement ($p < .05$). The incidence of joint sounds was the same for both groups.

ii Primary and Secondary Factors

A detailed analysis of the individual variables is shown in Appendix Table IX. The variables are divided into primary and secondary factors as discussed in the Methodology.

Since the cardinal symptom of joint sounds is the same as the individual factor of joint sounds (see Table II), this factor has been dealt with already under the section "Cardinal Symptoms". The incidence of the following pain factors was greater for the control group: TMJ and ear pain ($p < .001$), temple pain ($p < .05$), and movement pain ($p < .01$). Although the incidence of face pain was higher for the control group, the difference was not statistically significant. Limitation of opening had a higher incidence for the control group ($p < .01$),

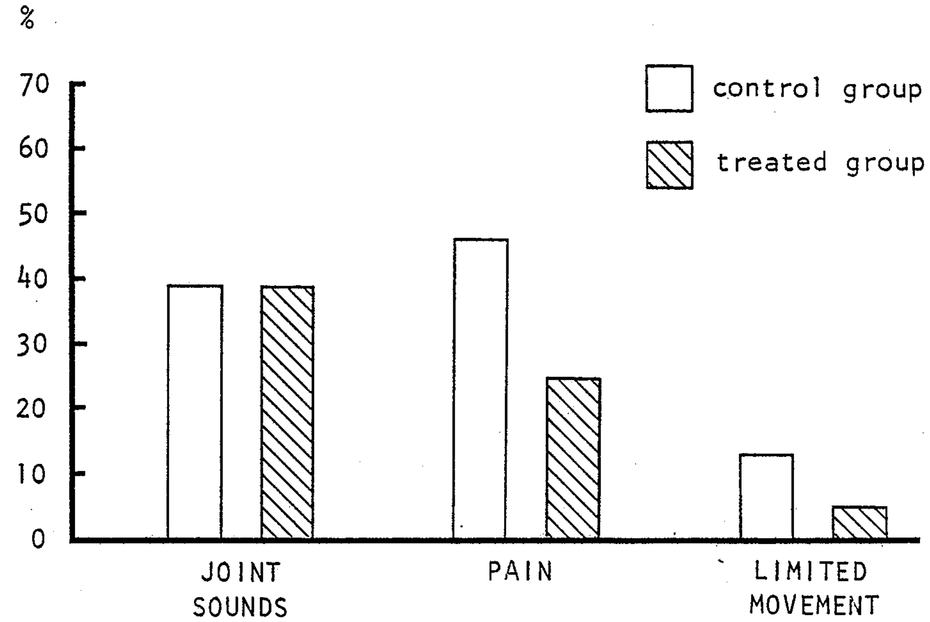

Figure 3. Percentage distribution of cardinal dysfunction symptoms for the control and treated groups.

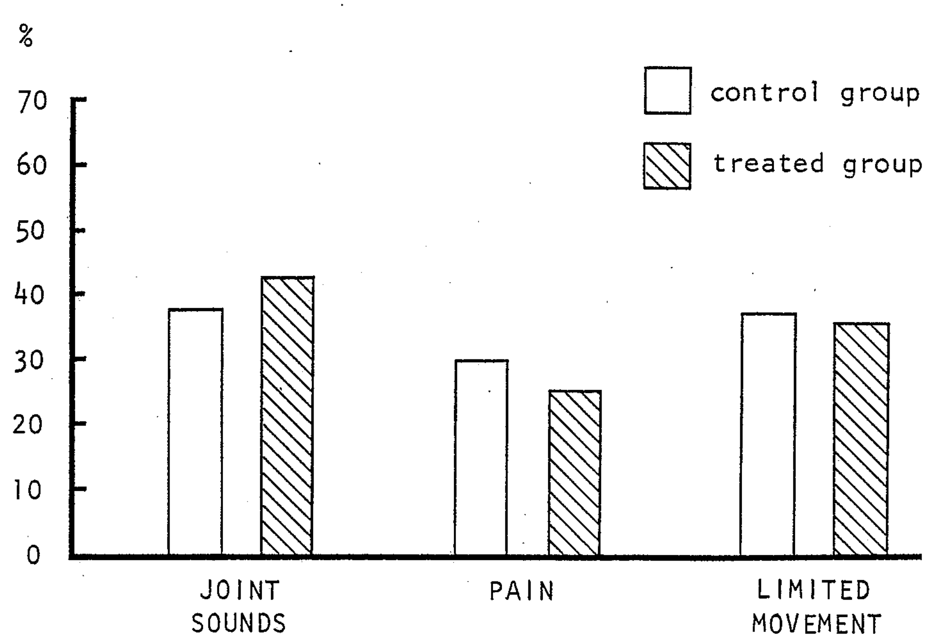

Figure 4. Percentage distribution of cardinal dysfunction signs for the control and treated groups.

but although subluxation/dislocation was higher for the control group, the difference was not significant.

For the secondary factors, the incidence of stiff or sore neck, back pain, and sore or swollen body joints was higher in each case for the control group ($p < .01$).

iii Indices

The various indices used in this study are described in the Methodology. A comparison of index values for control and treated groups is listed in Appendix Table X. Each index will be discussed individually along with the corresponding examination.

iv Anamnestic Dysfunction Index

The Anamnestic Dysfunction Index (ADI) is a composite index indicating severity of dysfunction symptoms. Index values increase with increased dysfunction. The comparison between control and treated groups for the distribution of ADI values is shown in Appendix Table X. The control group had more dysfunction ($p < .01$).

b) Clinical Examination

i Cardinal Signs

The difference in incidence of the cardinal signs between the control and treated group is shown in Figure 4. There was no statistically significant difference for any of the cardinal factors when comparing control and treated groups.

ii Primary and Secondary Factors

A detailed analysis of the individual primary and secondary factors is shown in Appendix Table XI. There was no statistically significant difference between control and treated groups for any of these factors. Continuous variables are found in Appendix Table XII. Maximum protrusion was less for the control group at 8.0 mm. in comparison to the treated group at 8.8 mm. ($p < .001$).

iii Clinical Dysfunction Index

The Clinical Dysfunction Index (CDI) as described in the Methodology is a composite index indicating severity of dysfunction signs found in the clinical examination. Higher index values indicate increased dysfunction. The comparison of the distribution of CDI values between control and treated groups is shown in Appendix Table X. There was no statistically significant difference in dysfunction between the two groups.

iv Subjective Assessment of Dysfunction

After the examination was complete, the examiner evaluated the severity of dysfunction according to his subjective assessment. The subjects were assigned to three groups depending on the severity of dysfunction. Only two subjects were classified as having severe dysfunction. The other subjects had either no dysfunction or moderate dysfunction. A comparison of the control and treated groups for distribution of the subjective dysfunction assessment is shown in Appendix Table X. There was no statistically significant difference between the two groups for dysfunction.

c) Occlusal Examination

Occlusal factors are listed in Table III in the Methodology.

Many of the factors evaluated during the occlusal examination go into making up the Treatment Priority Index (TPI) of malocclusion. Rotated and displaced teeth, crossbites, and molar and cuspid relationships are such factors, and were not evaluated separately under the occlusal examination. The factors which were evaluated are shown in Appendix Tables XIII and XIV.

i Primary Factors

The number of missing teeth was small, but was statistically greater for the control group at a mean of 0.39 as compared to the treated group at 0.02. Orthodontic extractions were not included in this calculation.

The mean overjet was greater for the control group at 4.6 mm. as compared to 2.8 mm. for the treated group ($p < .05$). The mean overbite for the respective groups was 5.4 mm. as compared to 3.5 mm. This difference was not statistically significant.

ii Secondary Factors

The incidence of "dorsally locked mandible" was greater in the control group at 9% as compared to the treated group at 1.2% ($p < .01$).

The treated group had more restored posterior tooth surfaces as compared to the controls ($p < .05$).

Third molar extractions were more common in the treated group at 13.5% as compared to 6.5% for the controls ($p < .05$).

iii Severity of Static Malocclusion

The Treatment Priority Index (TPI), as described in the Methodology, indicates the need for orthodontic treatment. The mean TPI score for the control group was 6.3, indicating definite malocclusion requiring treatment, while the mean score for the treated group was 2.3, indicating minor manifestations of malocclusion with only slight need for treatment. The differences between the two groups were significant ($p < .001$).

The examiner's subjective assessment of the need for orthodontic treatment indicated that 63% of the control group were in need of orthodontic treatment as compared to 12% of the treated group.

d) Functional Examination

i Individual Factors

Functional factors are listed in Table III in the Methodology.

The differences in the types of lateral guidance during jaw function between the treated and control groups is shown in Figure 5. Sixty-one percent of the treated group exhibited cuspid guidance. The control group had 39% cuspid guidance and only slightly less group guidance. The control group also had more unusual types of guidance, such as guidance by one posterior tooth. The differences mentioned are statistically significant ($p < .001$).

Balancing contacts on one or both sides were more prevalent in the control group at 34% as compared to the treated group at 25%. These differences were not statistically significant. Point centric was found in 19% of the treated group and 26% of the control group.

Figures 6 and 7 show incidence and mean length of anterior and lateral centric slides. The mean anterior slides in centric for the treated and control groups were 0.62 mm. and 0.56 mm. Anterior slides greater than 1 mm. occurred in 6% and 5% of the respective groups. Average lateral slides were 0.27 mm. and 0.21 mm. Lateral slides greater than 0.5 mm. occurred respectively in 13% and 8% of these groups. None of the differences between the two groups was statistically significant.

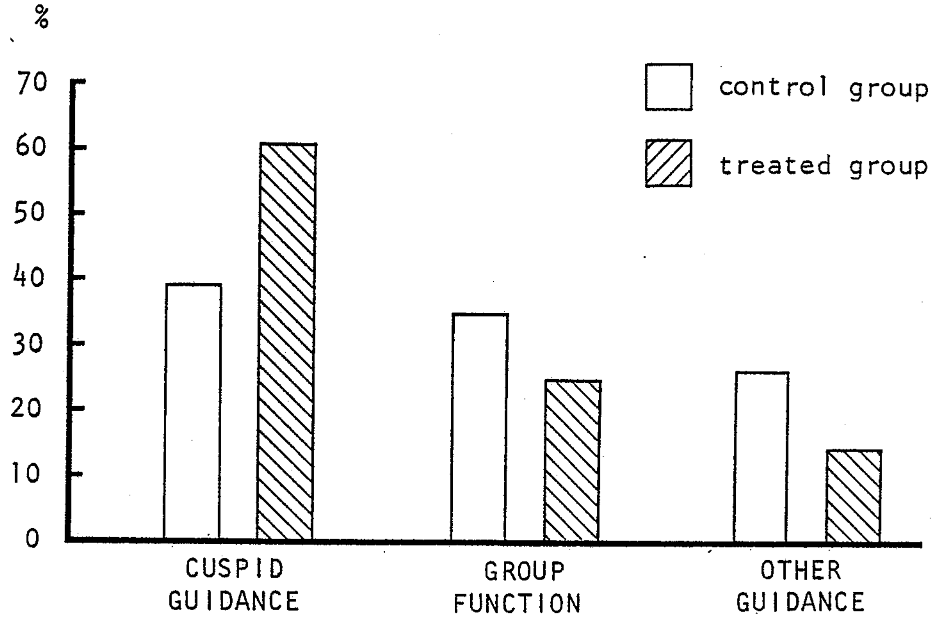

Figure 5. Percentage distribution of the different type of lateral guidance for the control and treated groups.

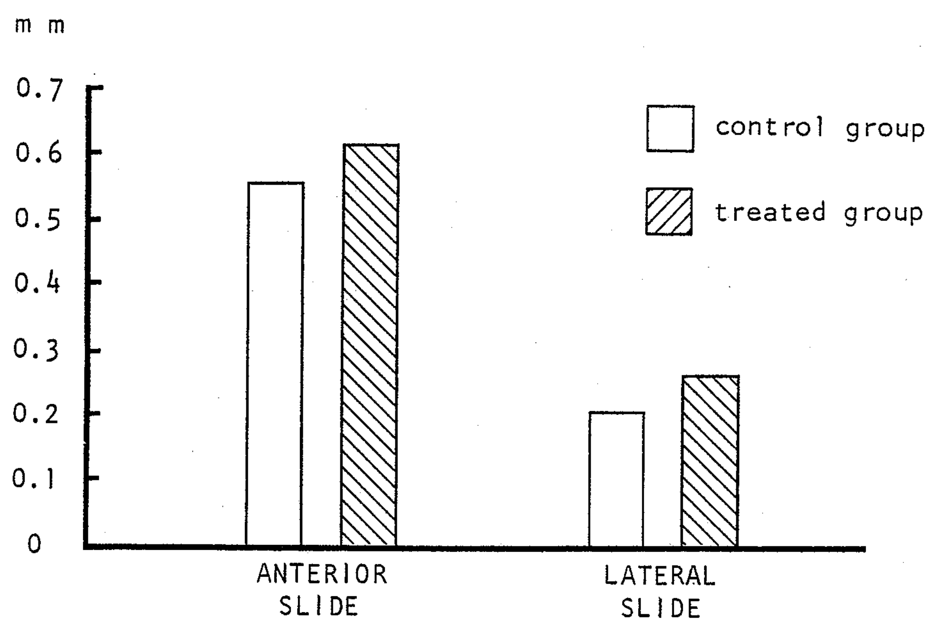

Figure 6. Mean values of anterior and lateral centric slides in the control and treated groups.

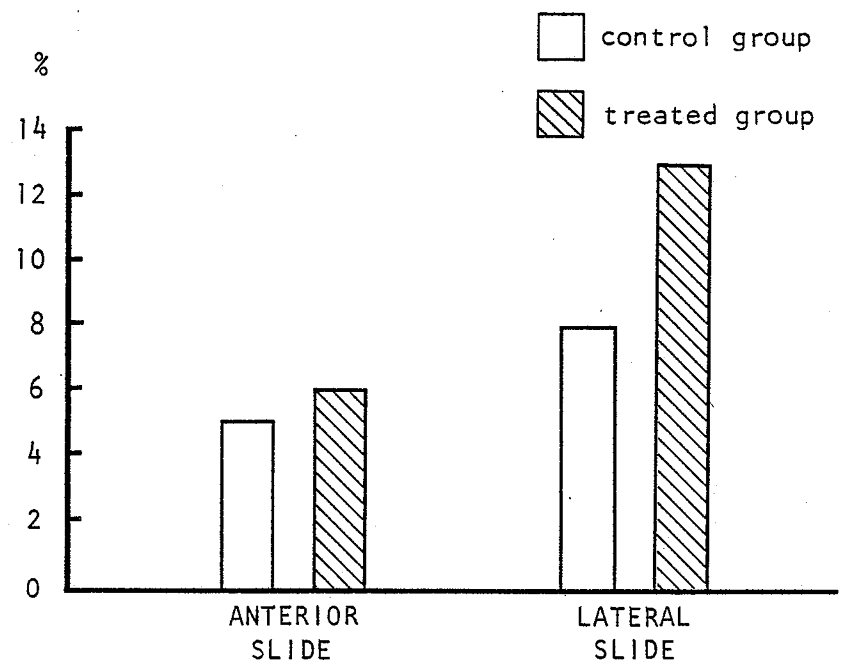

Figure 7. Percentage distribution of subjects with anterior slides greater than 1 mm and lateral slides greater than 0.5 mm in the control and treated groups.

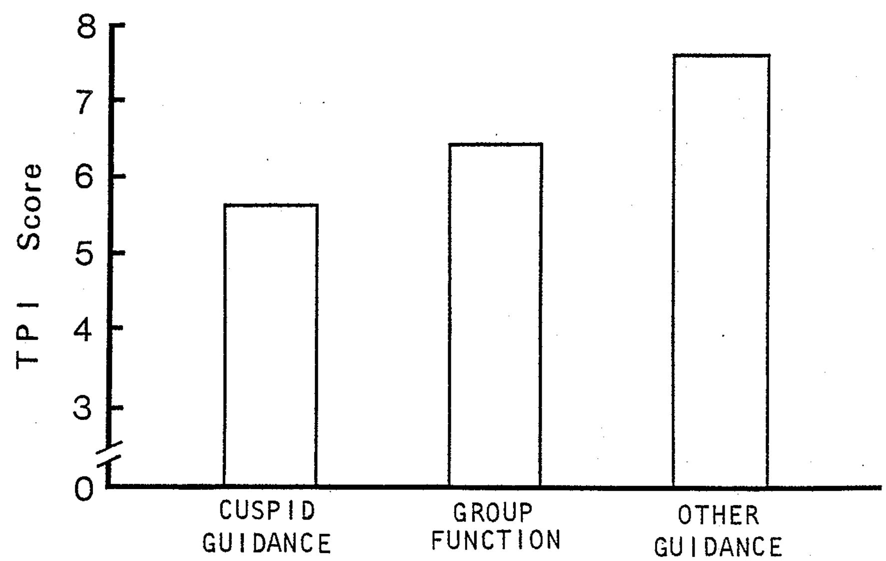

Figure 8. Mean TPI scores for the various types of lateral guidance found in the control group.

ii Functional Indices

The Articulation Interference Index (AII), as described in the Methodology, increases in value with increase in balancing side contacts and unusual guidance on lateral excursions. Index values are shown in Appendix Table X and are higher for the control group ($p < .001$).

The Centric Slide Index (CSI) increases in value with increased distances of lateral and anterior slides from RCP to IP. The distribution of index values are shown in Appendix Table X and are not significantly different when comparing control and treated groups.

Comparisons of Subgroups Using Indices

The major treated and control groups are made up of subgroups (see Methodology). Using mean index values for each subgroup, the subgroups within each major category can be compared as shown in Appendix Table XV.

Results of these comparisons within the treated group show that significant differences exist only between subgroups T-HS1 and T-UofW for ADI. ADI values are higher for the latter ($p < .05$). No other significant differences were found.

Within the control category, C-Clinic had higher TPI scores than the remaining subgroups ($p < .01$). C-UofW had significantly higher ADI values than subgroups C-Clinic ($p < .05$), subgroups C-HS1 ($p < .01$) and C-HS2 ($p < .01$). Subgroup C-HS2 had higher CSI values than C-UofW ($p < .05$).

The Relationship of Static Malocclusion to Dysfunction and Functional Factors

The Treatment Priority Index (TPI) is an accurate indicator of the severity of static malocclusion. Using the TPI, the relationship between static malocclusion and the dysfunction factors in the anamnestic and clinical examinations can be easily assessed. The relationship between static malocclusion and functional occlusal factors in the functional examination can also be evaluated with the aid of the TPI.

Because static malocclusion, and hence the TPI, is greatly altered by orthodontic treatment, the treated group was eliminated from this aspect of the study. The examination of the relationship of TPI to dysfunctional and functional factors was carried out using only the sample of 201 individuals in the control group.

a) Anamnestic and Clinical Examination Factors

Appendix Table XVI shows the relationship between TPI and primary and secondary dysfunction factors for the anamnestic examination. The mean TPI values were compared between subjects with the factor absent and subjects with the factor present, in order to evaluate the relationship between dysfunction factors and static malocclusion. It was found that there was no relationship between TPI and any of the factors evaluated.

Appendix Table XVII was designed to evaluate the relationship between TPI and primary and secondary factors in the clinical examination. The only factor showing a relationship was crepitus, which was related to higher TPI scores ($p < .05$).

b) Functional Factors

The relationship of TPI to types of lateral guidance is shown in Figure 8. The highest TPI scores were associated with increased incidence of unusual lateral guidance. The lowest TPI scores were found associated with cuspid guidance. Scores for group function were in the intermediate range. These associations were statistically significant ($p < .05$).

Higher TPI values were found in association with balancing side contacts, but the relationships were not statistically significant.

c) Indices

The relationship of TPI to the various indices used in this study is shown in Appendix Table XVIII. TPI scores increased with higher values of all indices including the examiner's subjective assessment of severity of dysfunction. However, the increase in TPI scores was not at the level of statistical significance.

Relationship of Dysfunction and Individual Factors

a) Associated Dysfunction Factors

Associated dysfunction factors are those which in previous studies have been found to be positively related to mandibular dysfunction. The ADI and CDI reflect the severity of dysfunction in the anamnestic and clinical examinations, and are convenient to use when assessing the relationship between mandibular dysfunction and associated dysfunction factors. This relationship is shown in Appendix Table XIX. The entire sample was used in calculating these associations.

ADI was positively related to headache ($p < .001$), neck pain ($p < .001$), back pain ($p < .001$), and a history of trauma ($p < .05$). The findings for the CDI were similar. CDI was positively related to headache ($p < .001$), neck pain ($p < .001$), and back pain ($p < .05$). There was no significant relationship between CDI and trauma.

Although there was a general trend towards a relationship between a history of bruxism and both ADI and CDI, the relationship was not statistically significant.

b) Functional Factors

ADI and CDI were used to examine the relationship between mandibular dysfunction and factors in the functional examination.

Figures 9 and 10 show the relationship of ADI and CDI to the mean length of lateral and anterior centric slides. None of the relationships were statistically significant, although there was a trend to decreased length of slides with increased CDI values.

Figures 11 and 12 show the relationship of ADI and CDI to point centric and balancing contacts. There was a positive association between increased incidence of point centric and both ADI and CDI, the latter association of statistical significance ($p < .05$). The incidence of balancing contacts increased with higher ADI values, though not at the level of statistical significance. There was no obvious association between balancing contacts and CDI.

When evaluating the relationship of lateral guidance to dysfunction, it was found that ADI was positively related to decreased incidence of cuspid guidance on right lateral excursion.

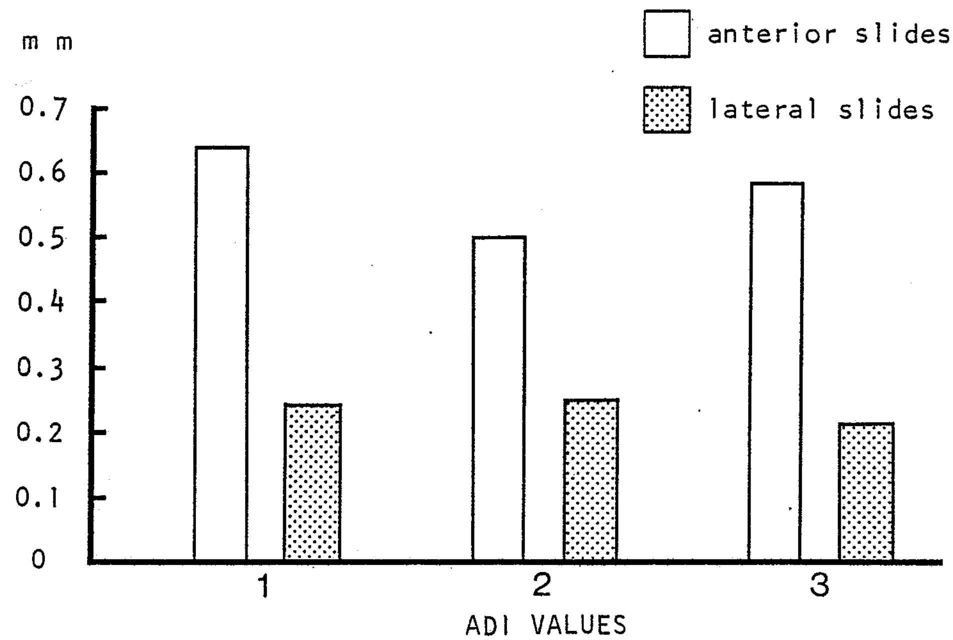

Figure 9. Mean length of anterior and lateral centric slides in the entire sample for the three ADI value categories.

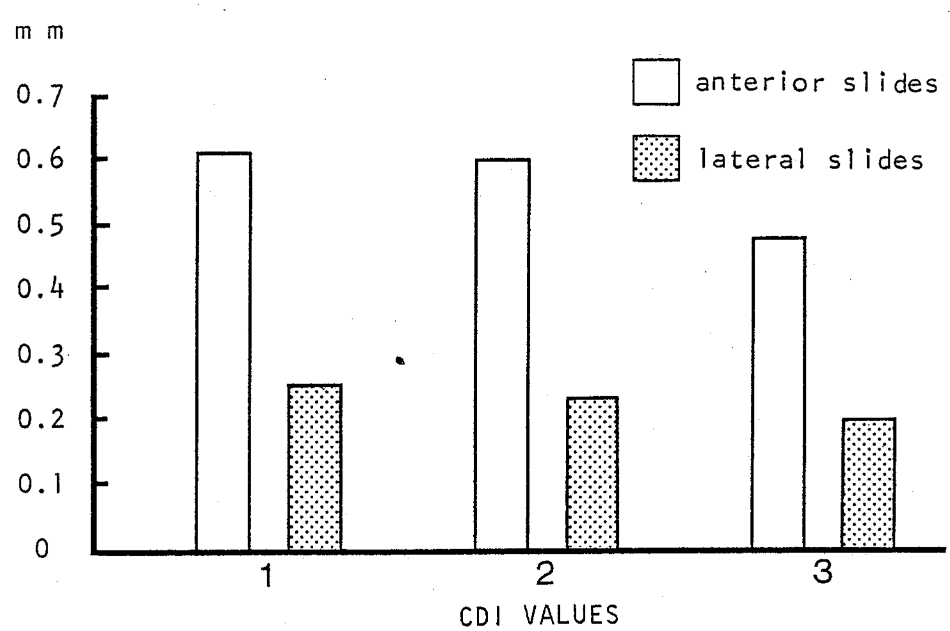

Figure 10. Mean length of anterior and lateral centric slides in the entire sample for the three CDI value categories.

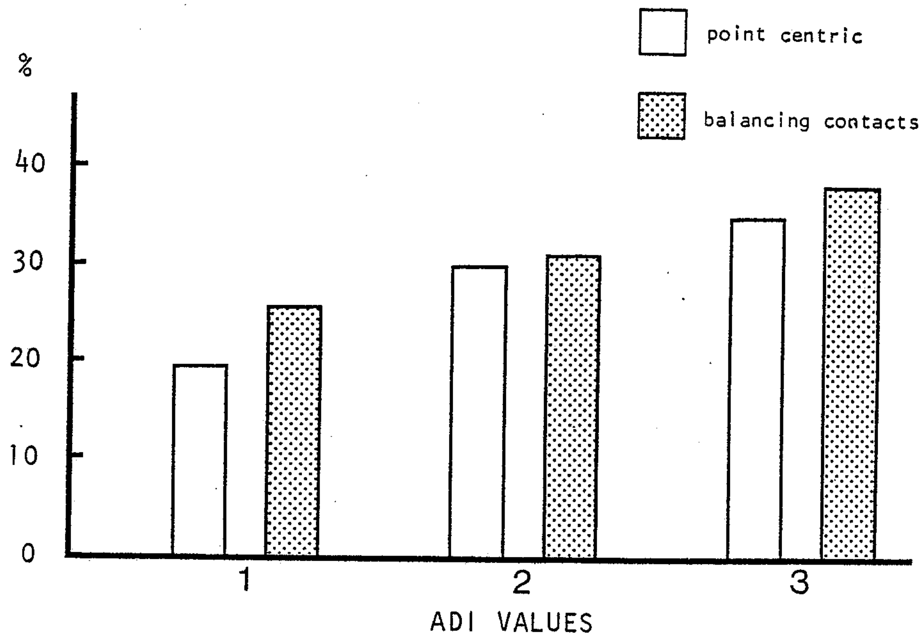

Figure 11. Percentage distribution of point centric and balancing contacts in the entire sample for the three ADI value categories.

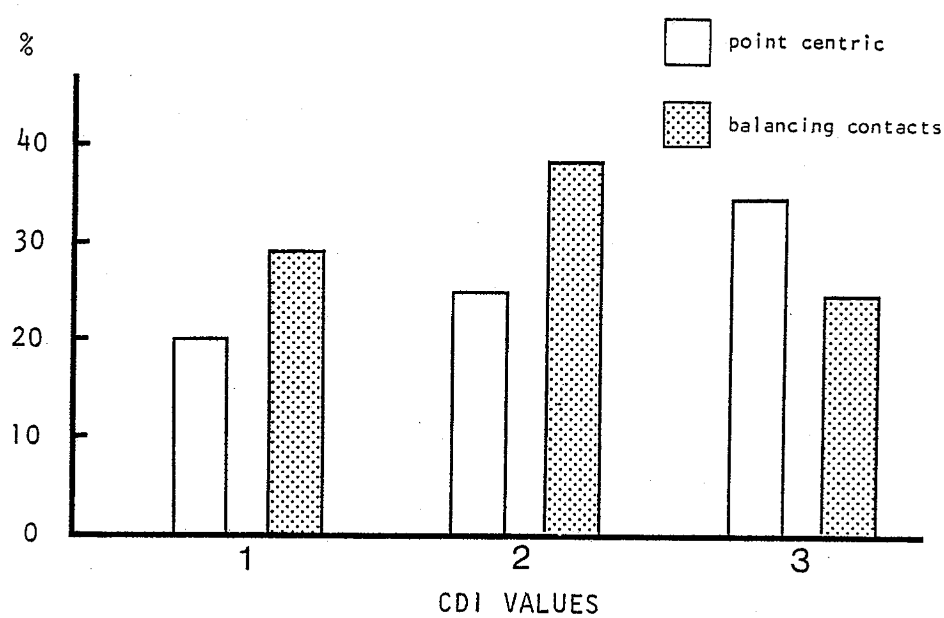

Figure 12. Percentage distribution of point centric and balancing contacts in the entire sample for the three CDI value categories.

c) Orthodontic Extractions

There was no significant difference in ADI or CDI values in comparing treated subjects who had undergone extractions for orthodontic purposes with subjects who were treated without extraction.

d) Time of Debanding

The time period since debanding varied from 6 months to 16 years. The mean time was 26 months with standard deviation 21.4.

There was no relationship between time since debanding and dysfunction indicated by either ADI or CDI.

Treatment Method

The treated subjects were asked where they had received orthodontic treatment and the types of appliances used. All received treatment by orthodontic specialists and all but one were treated with multiband appliances in one or both arches. One subject was treated with a monobloc.

Relationship of Age to Examination Factors

As described in the Methodology, the sample population was divided into three age groups as follows:

Age-1 - ages 12 to 15 years

Age-2 - ages 16 to 19 years

Age-3 - ages 20 to 30 years.

a) Cardinal Symptoms and Signs

Figures 13, 14 and 15 show the relationship of age group and

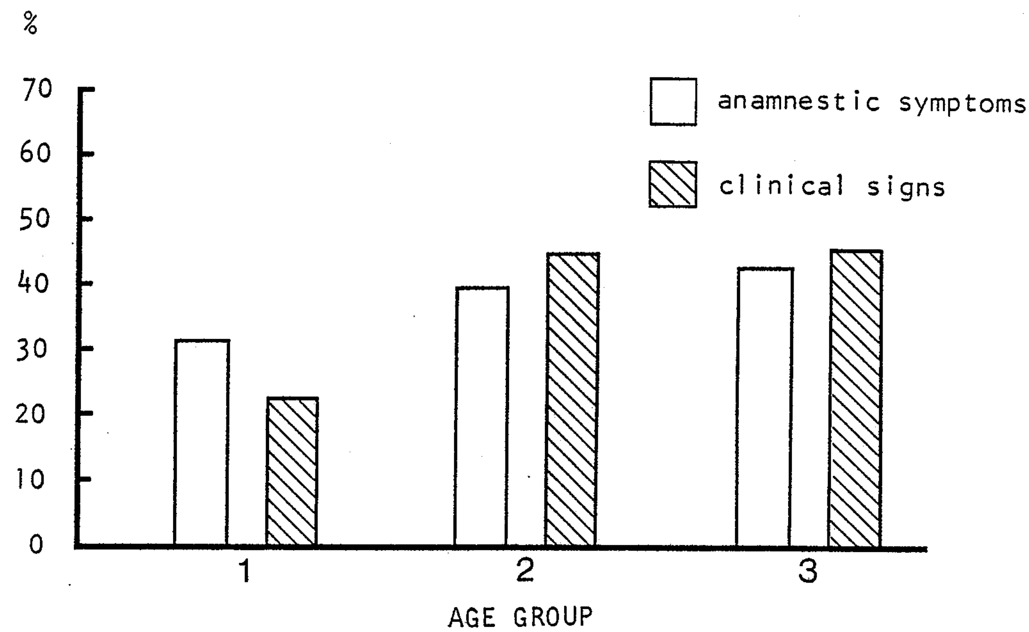

Figure 13. Percentage distribution of the cardinal symptom and sign of joint sounds in the entire sample for the three age groups.

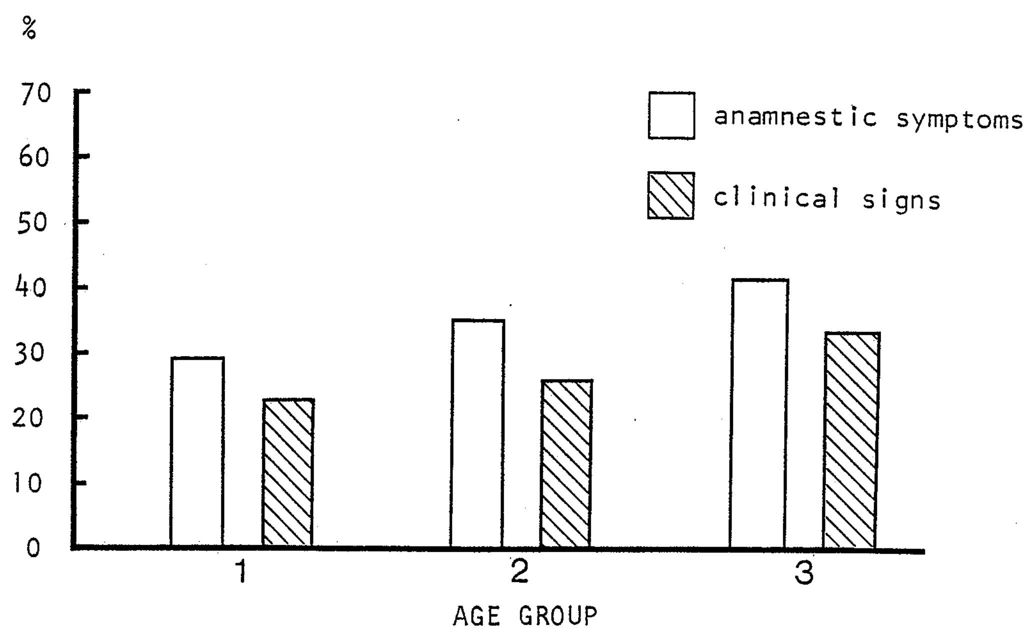

Figure 14. Percentage distribution of the cardinal symptom and sign of pain in the entire sample for the three age groups.

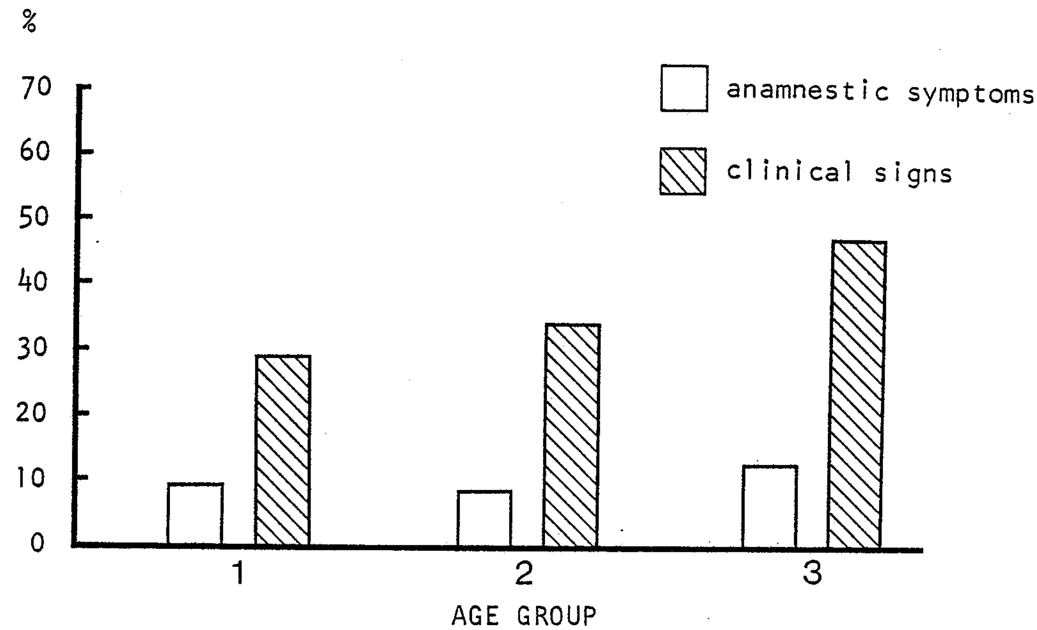

Figure 15. Percentage distribution of the cardinal symptom and sign of limited movement in the entire sample for the three age groups.

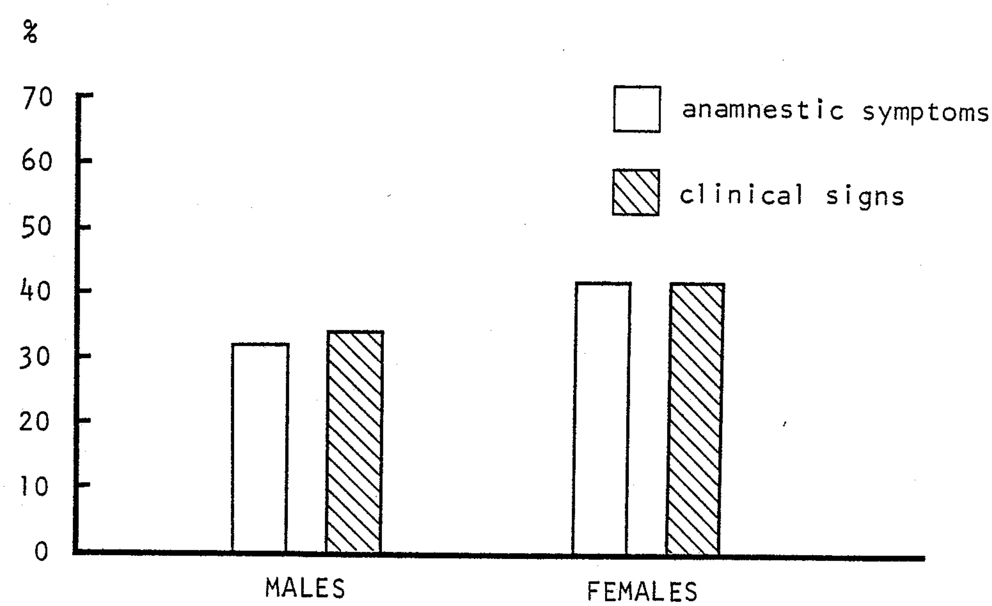

Figure 16. Percentage distribution of the cardinal symptom and sign of joint sounds in the entire sample for males and females.

cardinal dysfunction symptoms and signs. The cardinal symptoms are determined from the anamnestic examination and the cardinal signs from the clinical examination. All of the cardinal symptoms and signs increased in incidence with age with the exception of the symptom of limitation of movement. This symptom decreased slightly in the 16-19 year group. Of the symptoms and signs which increased with age, those of statistical significance were the cardinal signs of joint sounds ($p < .001$) and limitation of movement ($p < .001$).

b) Anamnestic and Clinical Examinations

The detailed results of the anamnestic examination are shown in Appendix Table XX. Increase in age was related to increase in the incidence of face pain ($p < .05$), neck pain ($p < .01$) and jaw fatigue ($p < .05$). A history of trauma was highest in the 16-19 year age group. All other factors in the anamnestic examination increased in incidence with age, though not at a level of statistical significance.

The detailed results of the clinical examination are shown in Appendix Table XXI. Increase in age was related to increase in lateral TMJ pain ($p < .001$), clicking ($p < .05$), crepitus ($p < .01$) and jerky jaw movements ($p < .001$). With the exception of pain on jaw movements, most other factors increased in incidence with increase in age.

Continuous variables are shown in Appendix Table XXII. All maximum mandibular movements decreased with age, with left lateral movements at the level of statistical significance ($p < .01$). Length of time since depending increased with age ($p < .001$).

c) Occlusal and Functional Examinations

Occlusal and functional factors in relationship to age are shown in Appendix Table XXIII. Dorsal locking was highest in the youngest age group ($p < .05$), while third molar extractions increased with age ($p < .001$).

Relationship of Sex to Dysfunctional and Occlusal Factors

The incidence of the cardinal dysfunction symptoms and signs in relation to sex is shown in Figures 16, 17 and 18. Females had a higher incidence of all cardinal symptoms and signs of dysfunction, with the exception of a history of limitation of movement. None of the differences was statistically significant.

The detailed results of the anamnestic and clinical examinations are shown in Appendix Tables XXIV and XXV. Females had a much lower incidence of trauma ($p < .01$) and a higher incidence of headaches ($p < .001$), and clicking. Although the difference was not statistically significant, a higher percentage of females had clinical findings of muscle and TMJ pain.

The relationship of sex to functional, occlusal, and other factors is shown in Appendix Tables XXVI and XXVII. Females had lower mean maximum jaw movements. Females had also slightly fewer missing teeth, but many more third molar extractions ($p < .05$).

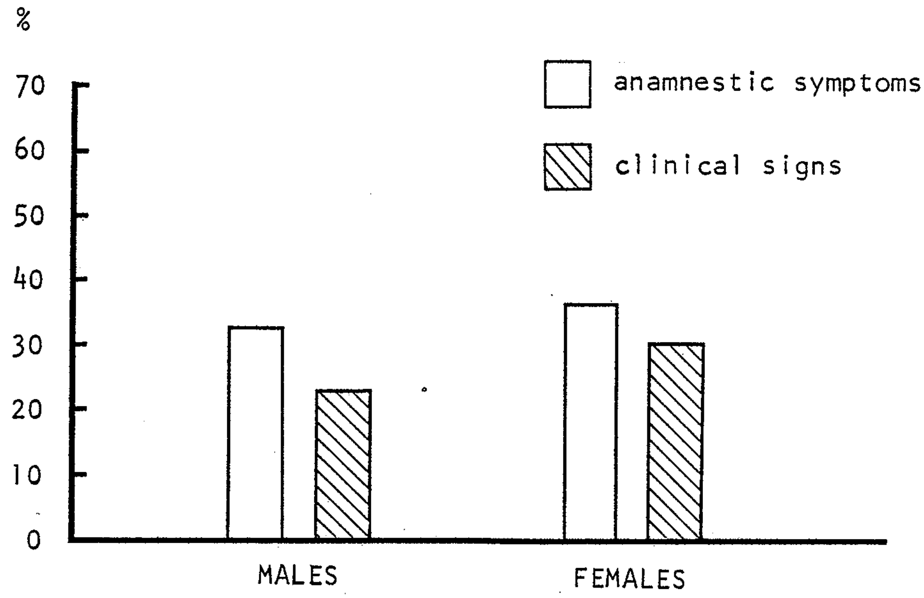

Figure 17. Percentage distribution of the cardinal symptom and sign of pain in the entire sample for males and females.

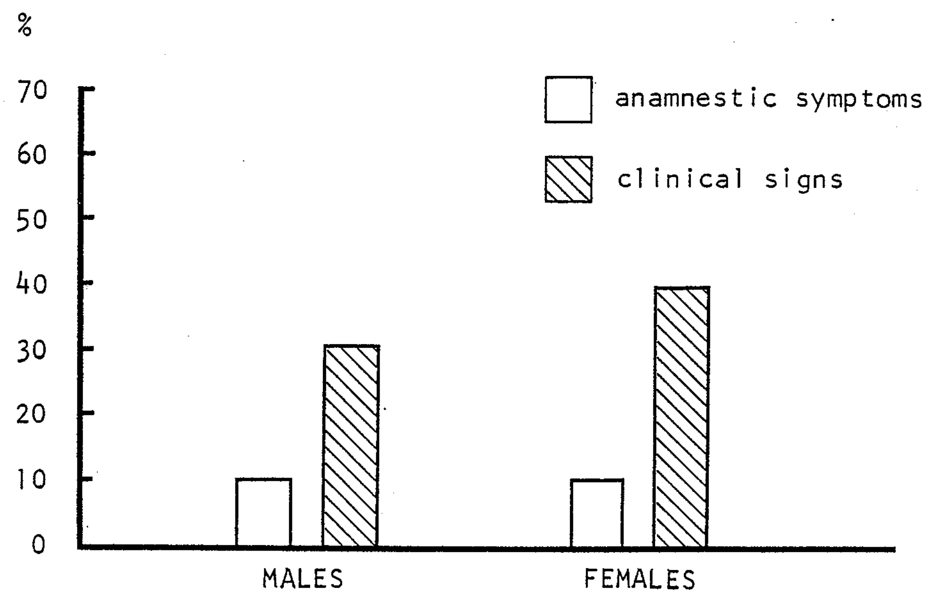

Figure 18. Percentage distribution of the cardinal symptom and sign of limited movement in the entire sample for males and females.

DISCUSSION

Surveys on Mandibular Dysfunction

Surveys on non-clinical subjects chosen at random have been valuable for increasing knowledge of the nature and extent of mandibular dysfunction in the general population. However, the results of findings of these studies must be interpreted with an understanding of their limitations. The anamnestic examination in particular has potential for substantial error because it relies on the subject's memory and interpretation of symptoms experienced. Kopp (1977) twice administered the same written questionnaire on dysfunction to the same subjects at an interval of one week and found the answers changed on average by about 22%. Meltzer and Hochstim (1970) found that survey data in general does not agree well with medical records, especially if the relevant condition is not serious.

The subject history can be taken by written questionnaire or verbal examination. Although a written questionnaire avoids the possible influence of the examiner on the subject, a verbal examination offered particular advantages for this study. Since even adults may have problems understanding simple written questions about dysfunction symptoms (Hansson and Nilner, 1975), the young subjects in this study would likely have had similar problems. Using a verbal approach, the examiner was able to assess the subject's understanding of a question and ask it in a different way if necessary. Furthermore, the examiner was able to choose the next question depending on the answer to the previous one. If the subject gave a positive reply for pain symptoms, he was then questioned about duration and predisposing etiological factors. The etiology of these symptoms may be unrelated to dysfunction. It has been shown in this study that possible etiological factors other than dysfunction account for up to 25% of pain symptoms in the area of the ears and TMJ, and up to 20% of pain symptoms on jaw movement.

The anamnestic examination presents further difficulties when comparing different studies. Although there is some agreement on what constitutes the major dysfunction symptoms, there is no agreement on how questions should be phrased.

Anamnestic examinations do offer an advantage over clinical examinations in that a patient is able to describe symptoms which he is no longer experiencing. This advantage is of particular importance in evaluation of mandibular dysfunction because the signs and symptoms tend to be cyclical in nature, often regressing and then reappearing.

The clinical examination is a more reliable indicator of mandibular dysfunction than the anamnestic examination because the examiner does not have to rely on the subject's memory. Many of the variables measured in this examination, such as those relating to static occlusion, do not rely on action or interpretation by the subject. Even measurements of maximum mandibular opening and protrusion, although they rely on jaw movement, have been shown by Kopp (1970) to be quite consistent when comparing examinations of a particular subject at different time intervals. When assessing centric slides, however, the examiner must rely on the subject's ability to relax the masticatory muscles sufficiently to allow manipulation of the mandible into centric relation position. The error here would be expected to be greater.

The diagnosis of pain during the clinical examination presents a particular problem because of the necessity of relying on subject interpretation. If the pain response is elicited by palpation rather than by the subject's own jaw movements, the problem in accurate diagnosis is compounded because the palpation technique may inadvertently vary between patients. The palpation of the lateral pterygoid muscle in a consistent manner presents particular problems because of difficulty of access and variation in patient anatomy.

Comparisons of studies using clinical examinations of dysfunction present similar problems to those using anamnestic examinations in that there is no standardized examination technique.

Because virtually all surveys vary due to type of population examined, as well as differences in number, sex, age, location, time, methodology, and other factors which may or may not be apparent, no two studies are totally comparable. However, the methodology in more recent studies has become more consistent, and the results of these studies are sufficiently comparable to reveal general trends concerning mandibular dysfunction.

The Sample

The main purpose of this research was to examine the influence of orthodontic treatment on mandibular dysfunction. To accomplish this goal, the incidence of dysfunction was compared between control and treated groups. For a reliable comparison, the treated group must be representative of the population of post-orthodontic individuals and the control group must represent a comparable population of untreated individuals. A serious potential obstacle in an accurate comparison of these groups would be a representation of dysfunction individuals beyond the norm for one of the groups. This problem did not arise in selecting the treated subgroup from the University of Manitoba and the control subgroup which sought orthodontic treatment at the University of Manitoba because all individuals who were eligible agreed to participate in the survey. The only subjects excluded were those in the latter subgroup who were seeking orthodontic treatment specifically for relief of dysfunction symptoms.

However, the selection procedure was different in the high schools and the University of Winnipeg, since volunteers were solicited but only a small portion of those asked agreed to participate. Since all potential volunteers were told that the study involved evaluation of malocclusion and "jaw problems", it is possible that individuals with dysfunction symptoms may have been more willing to volunteer. This possibility was unlikely for the high school subjects, as there was no significant difference in dysfunction between the high school subgroups and their comparable control and treated subgroups examined at the University of Manitoba. The subjects from the University of Winnipeg did, however, have a higher incidence of dysfunction signs and symptoms than the other subgroups in the study. The increased incidence can be explained by subject age, rather than bias in selection. The mean age of these students at 20.6 years was higher than that of the other subgroups. The incidence of mandibular dysfunction is highest in the 20-30 year age group as compared to the 12-15 and

16-19 year age groups. Furthermore, university students appear to have a higher incidence of dysfunction in comparison to a similarly aged non-student population. Wigdorowicz-Makowerowa et al. (1979) found that medical and military students had more dysfunction than similarly aged soldiers, likely because of higher levels of psycho-emotional factors. Because the University of Winnipeg students were included in both treated and control groups, comparisons of dysfunction between these major groups should still be valid.

Because a significant portion (31%) of the entire control group was made up of individuals seeking treatment for malocclusion, the control group had a higher incidence of malocclusion in comparison to the general population. Again, since the students in the high schools and university were told that the research concerned malocclusion, individuals with malocclusions may have been more willing to volunteer, further increasing the proportion of malocclusion individuals in the control group. The mean TPI score for the entire control group was 6.3, while Banack (1972) found in a random sample of 444 Winnipeg school children a mean TPI score of about 5. Since the TPI is an accurate index of static malocclusion, the control group in this study had more malocclusion than the general student population. However, as this survey was not designed to gather information on the epidemiology of malocclusion, the increased incidence of malocclusion in the control group is of minor importance, and should not have significantly affected the comparison of the incidence of dysfunction in orthodontically treated and non-treated groups.

Incidence of Dysfunction

The anamnestic examination revealed a high incidence of dysfunction symptoms in the sample group. This examination revealed that 58% of those questioned had at least one cardinal symptom of dysfunction. The incidence of dysfunction found in other studies is shown in Table VI. The incidence of dysfunction in the present study is higher than two other studies (Solberg, 1979; Hansson and Nilner, 1975). The differences could be because of actual differences in experiences of dysfunction symptoms by the groups studied, or because of difference in methodology, or both. On the other hand, the incidence of dysfunction symptoms, though not necessarily the severity, compares very favourably with studies by Helkimo (1976) and Agerberg and Carlsson (1972).

Even though the incidence of dysfunction appears high, many of the symptoms reported by the subjects were of a minor nature and transient as well. A history of occasional joint clicking or mild pain in or in front of the ears with no other symptoms does not constitute a problem requiring treatment. The percentage of subjects with two cardinal dysfunction symptoms is 18%--much less than the 35% with one cardinal symptom. The presence of three symptoms, indicating serious dysfunction, was experienced by only 5% of the sample.

The most common cardinal dysfunction symptom was joint sounds experienced by 39% of the sample, followed by pain at 36% and limitation of movement by 10%. The relative distribution of these three symptoms compares favourably with most other studies of dysfunction epidemiology.

Table VI

*Incidence of mandibular dysfunction and sex and age composition of the investigated populations in some epidemiologic studies

Authors	Number	Men:Women	Age (years)	Population	Prevalence of mandibular dysfunction: Subjective	Prevalence of mandibular dysfunction: Clinical
Studies on Children						
Grosfeld & Czarnecka (1977)	250	136:114	6-8	School children in Warsaw	-	56%
Wigdorowicz-Makowerowa et al. (1979)	2100		10-15	School children in Warsaw	-	16%
Studies on Adults						
Agerberg & Carlsson (1972)	1106	575:531	15-74	Inhabitants of Umea, Sweden	57%	
Hansson & Nilner (1975)	1069	82:987	20-65	Employees at a Swedish shipyard	23%	79%
Helkimo (1976)	321	165:156	15-65	Finnish Lapps	57%	88%
Ingervall & Hedegard (1974)	287	- :287	18-20	Army Inductees, Sweden	12%	
Molin et al. (1976)	253	- :253	18-25	Army Inductees, Sweden	12%	28%
Solberg et al. (1979)	739	370:369	20-40	University students in Los Angeles	26%	76%
Wigdorowicz-Makowerowa et al. (1979)	429			Medical students, Poland	-	57%
Studies on Orthodontic Patients						
Dibbets (1977)	112	63:49	8-17	Angle Class II Div 1 malocclusion, Holland	46%	

*adapted from Helkimo (1979)

As in nearly every study using both anamnestic and clinical examinations, the clinical examination revealed a higher proportion of dysfunction signs as compared to the anamnestic examination. Sixty-eight percent of those examined had at least one cardinal dysfunction sign. The incidence of dysfunction signs is comparable to most other clinical studies of dysfunction shown in Table VI. As with the anamnestic examination, the differences between this and other studies could be because of differences in the groups studied, differences in methodology, differences in factors unknown, or a combination of all three.

As in the anamnestic examination, the incidence of dysfunction appears high, but many of the dysfunction signs are of a minor nature. Of those with dysfunction signs, 23% had joint sounds as the only sign. Thirty-seven percent had one cardinal sign of dysfunction, 25% had two signs, while three signs, indicating serious dysfunction, was experienced by only 6% of the sample.

Joint signs, experienced by 39% of the population, was the most common sign, followed by limitation of jaw movement experienced by 37%, followed by pain experienced by 28%. The high percentage with limitation of jaw movement reflects the method used by Helkimo (1974 II) in evaluating restrictions in normal maximal mandibular movements. Most studies confine evaluation of limitation of movement to maximum mouth opening. Helkimo measured limitation of lateral and protrusive movements as well, and his method was used in the present study. A higher probability then exists for finding movement restrictions.

The incidence of pain in the anamnestic examination at 36% is higher than that found in the clinical examination at 28%. This higher incidence likely reflects the inclusion of ear and TMJ pain in the anamnestic evaluation. It is quite likely that earache is often related to factors other than dysfunction. In the entire sample 17% gave a history of pain in or in front of the ears. If even half of these subjects had predisposing causes for these symptoms other than dysfunction factors, the incidence of pain would drop considerably.

There was not complete agreement when comparing the findings of the anamnestic and clinical examinations. Fourteen percent of the subjects reported a history of dysfunction symptoms, but were not found to have dysfunction signs. The cyclic or intermittent nature of dysfunction explains this discrepancy, in that the symptoms once experienced were not present, at the time of examination. Twenty-four percent of subjects were found to have dysfunction signs, but no dysfunction symptoms. Unless the dysfunction signs are serious, they may not be noticed by the subject. As shown in Table VI, other studies on dysfunction have revealed that the incidence of dysfunction signs commonly exceeds the awareness of dysfunction symptoms. The stringent guidelines used for determination of limited jaw movement, as previously discussed, likely contributed to the high percentage of the subjects with dysfunction signs but no dysfunction symptoms.

The subjective evaluation of dysfunction by the examiner was found to relate significantly at a high level of confidence to both the Anamnestic Dysfunction Index (ADI) and the Clinical Dysfunction Index (CDI). This evaluation revealed that 89% of those examined had no dysfunction or dysfunction of a sufficiently minor nature that treatment was not required. Of those with at least one dysfunction symptom or sign, only 13% had dysfunction sufficiently severe that treatment would likely have been beneficial. Only two subjects in the entire sample had dysfunction so severe at the time of examination that they were unable to function without acute pain or severe alteration in normal jaw movement.

Of the entire sample, only three subjects had previously sought treatment for dysfunction symptoms. This low number likely reflects a combination of a low incidence of serious dysfunction problems, a reluctance to seek treatment and an ignorance of the opportunities for treatment.

Relationship of General Body Symptoms to Mandibular Dysfunction

Statistical evaluation revealed that subjects who manifested the signs and sumptoms of mandibular dysfunction tended to have more headaches, neck pain and back pain. Though the association was not statistically significant, pain and swelling of body joints increased with increase in dysfunction. These findings accurately reflect those of other studies which found strong associations between dysfunction and general joint and muscle symptoms and headache (Berry, 1969; Agerberg and Carlsson, 1973; Helkimo, 1976; Heloe, 1976). The association between dysfunction and these factors has not been completely explained. The psychologic theory of the origin of dysfunction stresses centrally-induced hyperactivity of muscles due to emotional stress. It seems reasonable to assume that hyperactivity and resulting muscle spasms could give rise to dysfunction symptoms as well as headache, neck pain, and backache. When also considering that individuals with dysfunction tend to have general joint symptoms, it seems plausible that dysfunction may also be a manifestation of poor general health. Agerberg and Carlsson (1975) stress the interaction of psychoemotional factors, impaired general health, and unstable occlusion in the etiology of mandibular dysfunction. At present, this explanation seems reasonable.

Although a history of bruxism was related to dysfunction, the association was not statistically significant. Those who brux may not be aware of their activity, so the incidence of bruxism and its relationship with dysfunction may be underrated. Although bruxism may be a significant factor in the etiology of dysfunction, it is only one of many other significant etiological factors.

The incidence of previous trauma to the jaws was related to an increase in dysfunction symptoms. However, because the incidence of trauma increased with age and the incidence of dysfunction symptoms also increased with age, the relationship may be coincidental. Males had a much higher incidence of previous trauma than females, but had no more dysfunction. Trauma did not appear to be a significant factor in the etiology of dysfunction.

Sex and Dysfunction

The evaluation of individual dysfunction factors indicates that 37% of females exhibit clinical signs of joint clicking as compared to males at 22% ($p < .01$). Twice weekly headaches were experienced by 28% of females and only 12% of males ($p < .001$). The cardinal symptom of pain was 12% higher in females while cardinal pain signs were 15% higher for females. The cardinal sign of limitation of movement, though higher for females, likely reflects anatomical differences in maximal jaw movements rather than the presence of dysfunction. Agerberg (1974) found in his sample of asymptomatic subjects of mean age 20, females had 5.3 mm. less maximum mouth opening. The difference in the present study is only 3.9 mm.

These findings of slightly increased dysfunction in females reflect closely the results of all epidemiological studies on non-clinical subjects which show that females suffer equally or only slightly more from dysfunction in comparison to males.

The results of this study and others make it apparent that the high ratio of females to males in patients presenting for treatment of dysfunction does not reflect the incidence of dysfunction in the population at large.

Age and Dysfunction

The results of this study indicate a marked increase in dysfunction with increase in age. The incidence of dysfunction was lowest in the youngest (12-15) year age group, higher in the intermediate (16-19) year group, and highest in the oldest (20-30) year group. The increase occurred for both signs and symptoms of dysfunction as evaluated in both the anamnestic and clinical examinations. The increase of cardinal dysfunction signs noted in the clinical examination was particularly striking. Joint sounds doubled in incidence from 23% in the youngest age group, to 46% in the oldest ($p < .001$); crepitus alone increased by more than 400% ($p < .01$). Clinical signs of pain increased from 23% in the youngest group to 34% in the oldest. Clinical evidence of limitation of jaw movement increased from 29% for the youngest group to 47% ($p < .001$)

for the oldest group. This difference is particularly notable in that it would seem reasonable for a mature adult to have a greater range in jaw movement as compared to a young teenager. Mean maximum lateral movements were about 1 mm. less for the oldest group in comparison to the youngest, and maximum protrusion was 0.7 mm. less.

The results of the anamnestic examination indicate increases in all cardinal dysfunction symptoms when comparing the youngest and oldest age groups. The amount of the increase was not as great as that found in the clinical examination. Associated dysfunction symptoms, such as sore neck, sore back, and sore body joints, also increased in incidence with increased age.

Two other studies on mandibular dysfunction span the age range from early to late teens or adulthood. Wigdorowicz-Makowerowa et al. (1979) found the incidence of dysfunction to be more than twice as high for a group in their twenties as compared to the 10-15 year age group. Dibbets (1977) found that juvenile osteoarthrosis was evident in 5% of the 10 year olds but in 20% of 17 year olds in his sample group. Studies by Agerberg and Carlsson (1972) and Helkimo (1976) span the age groups from late teens to old age. They found that the 15 to 25 year age group had slightly less dysfunction and somewhat fewer severe symptoms of dysfunction as compared to the older age groups.

It therefore seems reasonable to assume that a large increase in the incidence of dysfunction occurs during the period from early teens to early adulthood.

Malocclusion and Dysfunction

a) Static Malocclusion

In studies by Geering-Gaerny (1971), Ingervall and Hedegard

(1974), Uzhumutskene (1974), and Wigdorowicz-Makowerowa et al. (1979), there was a positive relationship between mandibular dysfunction and either static malocclusion or a need for orthodontic treatment. The method of assessing the malocclusion was not generally reported.

In this study, in order to eliminate the possible effect of orthodontic treatment on dysfunction and because most post-orthodontic patients have little or no malocclusion, only the untreated group was used in assessing the relationship between static malocclusion and dysfunction. Because a malocclusion is usually a sum total of different components, the Treatment Priority Index (TPI) of Grainger (1967) was used to quantify malocclusion. This index has been found to accurately reflect the subjective assessment of malocclusion by orthodontists.

TPI values were compared between symptomatic and asymptomatic individuals. It was found that of all variables examined, only crepitus was significantly related to TPI. Pain on maximum jaw protrusion was almost significantly related to TPI. There was a general trend in the anamnestic examination for TPI to be related to dysfunction. TPI scores increased with higher ADI and CDI, though not at a statistically significant level. Indices which reflect articulation interferences and centric slides also showed positive relationships with TPI but not at a statistically significant level. Balancing side contacts were more prevalent with higher TPI values, but the relationship also was not statistically significant.

The sample of patients with Class II malocclusion and very large overjet was too small to test Rickett's (1953) findings of increased dysfunction in this type of individual.

There was no relationship between dorsal locking and dysfunction. However, at 20 individuals, the sample may also have been too small to adequately test this relationship.

In considering the role of static malocclusion on the dysfunction state, it seems appropriate to quote Rugh and Solberg (1979) once again:

> The probability that any one patient will present with dysfunctional symptoms is clearly dependent upon a staggering number of factors, many of which are not well understood.

Static malocclusion appears to be one of these "staggering number of factors".

b) Functional Malocclusion

Because functional occlusal factors have been associated with dysfunction signs and symptoms, and because both treated and control subjects would be affected by these factors, the entire sample was used to evaluate the effect of functional malocclusion on mandibular dysfunction.

Dysfunction did not increase with the length or incidence of lateral or anterior centric slides. There was a relationship between dysfunction symptoms and balancing side contacts, although not at a level of statistical significance. On comparing these results to other studies, investigations by Loiselle (1969), Helkimo (1974 III), Butler (1975), Heloe and Heloe (1975), revealed no association between dysfunction and either centric slides or balancing contacts.

Other researchers have found increased incidence of lateral centric slides and/or balancing side contacts in individuals with dysfunction (Posselt, 1963; Solberg, 1972; Molin et al., 1976; Barghi, 1978). Even in the latter studies, however, these types of functional discrepancies are not found in all dysfunction individuals. Furthermore, it has been shown that such discrepancies are commonly found in individuals with no signs or symptoms of dysfunction (Ingervall, 1972; Solberg, 1979). It seems reasonable to assume that functional occlusal discrepancies may be one factor in the etiology of mandibular dysfunction, but the presence or absence of dysfunction depends, in most cases, on the interaction of a host of etiological factors.

The incidence of point centric was significantly higher in subjects with more evidence of clinical dysfunction. It is a common clinical observation that it is often difficult to manipulate the mandible into centric relation in individuals suffering from dysfunction symptoms. Muscle spasm or a fear of pain may prevent these patients from relaxing the muscles of mastication sufficiently for the mandible to assume a retruded position. The high incidence of point centric in these subjects likely results from inability to obtain a true centric relation.

Psychologic Factors and Dysfunction

Psychologic factors per se were not evaluated in this investigation. Although these factors likely play a role in dysfunction etiology, they are difficult to evaluate. Few other studies on dysfunction epidemiology have attempted to evaluate psychologic differences between subjects. For comparisons in the present study the control and treated groups were matched as closely as possible in order to minimize psychologic differences among the various subgroups.

Comparison of Treated and Control Groups for Occlusion and Dysfunction

a) Occlusal and Functional Factors

As expected, the treated group had a much lower incidence of static malocclusion in comparison to the control group. However, the occlusions in the treated group were by no means perfect. It was found according to the examiner's subjective assessment, that 12% of those treated could benefit from further orthodontic treatment.

The treated group had more restored tooth surfaces and fewer missing teeth (excluding teeth extracted for orthodontic purposes) than did the control group. This difference probably reflects the better general dental care that the treated group had received in comparison to the controls. The higher incidence of third molar extractions for the treated group might indicate a lack of space in the jaws for these teeth in individuals with malocclusions. It is more likely that extractions of these teeth indicates more routine dental care. Many dentists, and particularly orthodontists, advise extraction of these teeth even if they are asymptomatic.

The difference between the control and treated groups for the mean length of lateral and anterior centric slides was minimal and statistically insignificant. The incidence of lateral centric slides greater than 0.5 mm. was 8% for the control group and 13% for the treated group. This difference was not statistically significant, and in this study there was no relationship between such centric slides and dysfunction. The incidence of point centric was higher for the control group and point centric was found to be associated with dysfunction. Balancing side contacts, which were found to be weakly associated with dysfunction symptoms, were more prevalent in the control group at 34% than in the treated group at 25%.

There were significant differences in the types of lateral guidance between the two groups. In the control group, cuspid guidance and group function occurred with almost equal frequency at about 37% on both right and left sides. In the treated group, the prevalence of cuspid guidance at about 61% on both right and left sides was more than double that of group function. The incidence of unusual types of guidance was higher for the control group and was found in approximately 26% of subjects on the right and left sides, whereas the incidence in the control group was much less at about 14% on both sides.

From the perspective of function, it therefore appears that the occlusion found in the treated group was somewhat superior to that of the control group. There may be several explanations for the difference. The orthodontic treatment may have been carried out with a prime objective of establishing an occlusion which would work in harmony with the functioning of the TMJs. However, it has only been in the last several years that the establishment of a functional occlusion has been an important objective at the University of Manitoba Graduate Orthodontic Clinic where the vast majority of the subjects received orthodontic treatment. A more likely explanation is that if teeth are put into a position of harmony according to the traditional orthodontic guidelines for static occlusion (1-3 mm. of overbite, 0-2 mm. of overjet, Angle Class 1 cuspid relationship, no rotated teeth, no crossbites), they are more likely to be in functional harmony with the TMJs than are teeth arranged in the original malocclusion. This explanation does not mean that balancing side contacts and other functional discrepancies do not occur in ideal static occlusion, for obviously they do according to the findings of this and other studies. However, not only is the incidence of their occurrence less than in the population of untreated subjects, but some of the balancing contacts in the treated group may have developed after orthodontic treatment because of eruption of second or third molars or because of change in occlusion due to growth.

Two conclusions are evident from this discussion. In the population studied, functional occlusion was somewhat superior in the group treated orthodontically as compared to the control group. However, since lateral centric slides and balancing contacts were common even in the treated group, more care must be taken during orthodontic treatment to establish not only an ideal static occlusion, but an ideal functional occlusion as well.

b) Dysfunctional Factors

The results of comparing the treated and control groups using data gathered in the anamnestic examination shows dysfunction to be significantly higher for the control group. A history of the cardinal symptom of pain was given by 46% of the control group as compared to 24% of the treated group. A history of limitation of jaw movement was given by 13% and 5% of the respective groups. The incidence of jaw sounds was identical. Even the associated factors such as neck pain, back pain and joint pain were higher for the control group.

There does not appear to be an obvious explanation for the difference in incidence of these variables. In this study, dysfunction has been found to increase with age, and yet the mean age of the control group is 17.3 years as compared to 18.3 years for the treated group. Females have somewhat more dysfunction than males, and yet the ratio of females to males is higher in the treated group than in the control group. Bias in sample selection, as mentioned previously, may have resulted in the control group being more heavily weighted for subjects with symptoms of dysfunction.

Another possible explanation is the difference in functional occlusion between the two groups. The control group had more balancing side contacts and more unusual types of lateral guidance. These factors may play a role in the etiology of dysfunction symptoms. The control group also had a much higher incidence of static malocclusion as compared to the controls. Findings of this and other studies have shown that some dysfunction symptoms increase with need for orthodontic treatment.

As previously discussed, the anamnestic examination has considerable potential for error, which may account for some of the differences found between the two groups. The findings of the clinical examination are more reliable.

The results of the clinical examination indicate that there is no significant difference for any variables between the treated and control groups. The only exception is 1 mm. less maximum jaw protrusion for the control group. The results indicate no effect of orthodontic treatment on dysfunction.

If post-orthodontic individuals do not suffer more from dysfunction in comparison to the untreated population, then what is the explanation for the supposed high ratio of the post-orthodontic population among those undergoing treatment for dysfunction? Firstly, the number of patients receiving orthodontic treatment has increased dramatically in the last 20 years, both in absolute numbers and as a percentage of the general population. Obviously, even if this treated group has the same incidence of dysfunction as the untreated population, they will make up a greater proportion of the dysfunction population than in the past.

Furthermore, the relationship between mandibular dysfunction and orthodontic treatment is based mainly on clinical observation. Similar clinical observation led clinicians to believe that 3 to 4 times as many females as males suffer from mandibular dysfunction. It was only when epidemiological studies of dysfunction were carried out in the general and selected populations that it became apparent that males suffer about equally from dysfunction as do females. The most likely explanation for the discrepancy between the clinical and epidemiological findings was a different illness behavior on the part of the female. Females were much more likely to seek treatment for mandibular dysfunction as were males. Similarly it seems very likely that post-orthodontic individuals would behave differently from the untreated population in reaction to dysfunction symptoms. The post-treatment group have more restorations and fewer missing teeth, indicating that they have sought dental treatment more often than the control group. Furthermore, because of the orthodontic experience, post-treatment patients become highly conscious of the oral-facial milieu. They are accustomed to seeking treatment from dental professionals. It seems reasonable that these individuals are much more likely to seek treatment for dysfunction symptoms than are the general population of untreated individuals.

The ratio of females:males who have had orthodontic treatment at the University of Manitoba is 2.5:1. This ratio is likely indicative of the entire post-treatment population. Females also seek treatment for dysfunction more often than do males. Therefore the increased likeliness of post-orthodontic patients to seek treatment for mandibular dysfunction is compounded by the high ratio of females in this population.

The one clinical study reviewed which showed increased dysfunction in post-orthodontic patients was that done in Britain by Franks (1967). In Britain, orthodontic therapy for Class II Division 1 malocclusion, the most common malocclusion treated, usually involves extraction of two upper bicuspids and tipping back of maxillary incisors with removable appliances (Fisk, 1979). In another British study Berry and Watkinson (1978) evaluated 18 post-orthodontic cases who presented with symptoms of joint clicking, muscle pain, and limitation of jaw movement. All at one time had Class II Division 1 malocclusions with large overjets. Most had been treated with extraction of two upper bicuspids and all underwent tipping back of maxillary incisors with removable appliances. The authors believe that the resulting deep overbite and minimal overjet (dorsal locking) restrict the normal freedom of condylar movement, resulting in mandibular dysfunction.

In the present study, dorsal locking was not found to be associated with increased incidence of dysfunction signs and symptoms. However, the number of subjects with this condition was too small for an accurate evaluation. In studies of subjects with static malocclusion, both Ricketts (1953) and Williamson (1977) observed that those with deep overbite and minimal overjet (dorsal locking) had particular evidence of dysfunction signs in comparison to subjects with most other types of malocclusion.

Studies by Dorph et al. (1975), Dibbets (1977) and Barghi (1978) all indicate that post-orthodontic patients are not more likely to suffer from mandibular dysfunction than are untreated individuals. The subjects in Dibbet's study were treated with Begg fixed appliances and monoblocs. Barghi's subjects were students and patients at a Texas dental school and were most likely treated with fixed appliances. Dorph et al. did not state the type of appliances used. Patients in the present study were treated with fixed appliances. Patients treated with fixed appliances and monoblocs are not likely to have the deep overbites and minimal overjet of those described by Berry and Watkinson (1978).

The influence of dorsal locking on mandibular dysfunction in the studies discussed is speculative. What is more pertinent is that in 3 of 4 previous studies, post-orthodontic patients were not found to have a higher incidence of mandibular dysfunction in comparison to untreated subjects. The present investigation backs up the findings of the majority of these relevant studies; in the population examined, individuals who have had orthodontic treatment did not have a higher incidence of the symptoms and signs of mandibular dysfunction than did untreated subjects.

CONCLUSIONS

The present study was undertaken to examine the effect of orthodontic treatment on mandibular dysfunction. Further purposes were to evaluate the incidence and nature of dysfunction in the teenage and young adult population, and to determine the influence of occlusal factors on the dysfunction state.

A total of 371 subjects in two major groups were examined. The treated group consisted of 170 subjects who had undergone orthodontic treatment. The control group consisted of 201 untreated subjects.

An anamnestic examination (oral history) and a clinical examination was carried out on each subject. The data gathered was grouped and classified using various indices and then statistically analysed. The findings warrant the following conclusions:

1. Mandibular dysfunction was a common occurrence in the population sampled. In the anamnestic examination, 58% of all subjects reported at least one symptom of dysfunction, while in the clinical examination, one or more dysfunction signs were found in 68% of the subjects. Forty-four percent of the subjects had both dysfunction symptoms and signs. Most dysfunction found was of a minor nature. Of the 304 subjects who were found to have at least one symptom or sign of dysfunction, only 13% required treatment according to the subjective assessment of the examiner.
2. Females suffered somewhat more from dysfunction than did the males. Clinical evidence of clicking was 68% higher in females

(p < .01), while signs and symptoms of pain were about 14% higher (p < .001). Most other dysfunction factors were higher for females, though not at the level of statistical significance.

3. Dysfunction signs and symptoms increased with age. In comparing the 12-15 years group with the 20-30 years group, pain signs increased by 39%. Crepitus increased fourfold (p < .01). Limitation of jaw movement increased by 62% (p < .001).
4. Subjects with dysfunction had significantly higher incidences (p < .001) of headache, neck, and back pain. General joint symptoms were also related to dysfunction.
5. There was a weak association between static malocclusion and dysfunction. A similar association existed when comparing static malocclusion to functional occlusal discrepancies, such as balancing contacts, lateral centric slides, and unusual lateral guidance (e.g. guidance by only one posterior tooth).
6. There was a weak association between balancing contacts, and mandibular dysfunction symptoms. There was no association between the length of direction of centric slides and dysfunction.
7. For functional factors, it was found that the mean length of lateral and anterior centric slides were slightly higher for the treated group, while the incidence of balancing contacts was higher for the control group, as was the incidence of unusual types of lateral guidance.
8. Orthodontic treatment was not found to be an etiological factor in mandibular dysfunction. Dysfunction symptoms reported in the anamnestic examination were more prevalent in the control than

the treated group. There was no difference between the control and treated group for dysfunction signs found in the clinical examination.

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APPENDIX

Table I

Consent forms used in the high schools

UM

THE UNIVERSITY OF MANITOBA
FACULTY OF DENTISTRY

PREVENTIVE DENTAL SCIENCE

780 BANNATYNE AVE.
WINNIPEG, MANITOBA
CANADA R3E 0W3

April, 1979.

Dear Parent,

As you may know, crooked teeth and some jaw disorders can be serious problems in teenagers. To better understand the extent of these problems and to increase our scientific knowledge in this area, I am conducting a study in the high schools.

I am a graduate dentist with 7 years experience. I am now studying orthodontics (braces) at the University of Manitoba.

Each consenting student will receive an examination of the teeth and jaw muscles. The examination takes about 10 minutes and will be carried out in the nurse's office. Since I am not checking for cavities, the examination is painless and does not involve the use of X-rays.

After all the examinations are complete, I will send home a note with the student describing my findings. There is no fee for any part of this service.

This research has the approval of the Winnipeg School Division #1, the School Principal, the Inter-University Research Committee, and the Dean of the Faculty of Dentistry.

To date, I have had good success at Grant Park School. I urge your co-operation. Please fill out the Consent Declaration and have your son/daughter return it promptly to the school.

If you have any questions, please call me at 786-3545.

Yours truly,
Dr. Peter Gold

CONSENT DECLARATION

Name of Student____________________ Birth Date __/__/__
d m y

☐ Student has never had braces
☐ Student is now wearing braces
☐ Student has had braces

Advisor/Home Room: ____________

PARENT'S SIGNATURE: I Consent ____________________

I Do Not Consent ____________________

Table II

Examination form: Anamnestic Examination

Location ______________________

Name ______________________

Sex ______________________

Date ______________________

Birthdate ______________________

Address ______________________

Phone ______________________

1. Ortho.: No ______ Yes ______
   Priv. ______ U. of M. ______
   Active ______ Multi. ______
   Deband ______ / ______

2. Headache: No __ Yes __ P.C.__ Dur.__ A __ B __ C __

3. Pain: Ear: No __ Yes __ P.C.__ Dur.__ A __ B __ C __
   Face: No __ Yes __ P.C.__ Dur.__ A __ B __ C __
   Temple: No __ Yes __ P.C.__ Dur.__ A __ B __ C __
   Neck: No __ Yes __ P.C.__ Dur.__ A __ B __ C __
   Back: No __ Yes __ P.C.__ Dur.__ A __ B __ C __
   Body joints: No __ Yes __ P.C.__ Dur.__ A __ B __ C __

4. Grind, clench: No __ Yes __ Dur.__ A __ B __ C __

5. Stiff, tired: No __ Yes __ Dur.__ A __ B __ C __

6. Movt. pain: No __ Yes __ P.C.__ Dur.__ A __ B __ C __

7. Limit open: No __ Yes __ Dur.__ A __ B __ C __

8. Sublux, Disloc.: No __ Yes __ Dur.__ A __ B __ C __

9. Noise: No __ Yes __ Dur.__ A __ B __ C __

10. Trauma: No __ Yes __

11. Prev. Tx.: No __ Yes __
    Drug ___ Splint ___ Equil ___ Oth. ___

Table III

Methodology of the Anamnestic Examination

The information gathered from the anamnestic examination was recorded on the form in Appendix Table II. The examination methodology was as follows:

1. Treatment with functional appliances (activator, etc.) or fixed multibanding was recorded as "yes" for orthodontic treatment. It was noted whether treatment was by private practitioner or at the University of Manitoba. Type of appliance (activator or multibanding) and date of debanding was recorded.

Consistent wording of the remaining questions was adhered to. Questions were asked as follows:

2. "Do you get headaches twice a week or more often?
3. "Do you get pain in or in front of your ears?"
   "Do you get pain on the side of your face?"
   "Do you ever feel pain here?" (finger was placed in temple area)
   "Do you get stiff or sore neck?"
   "Do you get backache?"
   "Do you get sore or swollen joints?"
4. "Do you grind your teeth at night, or do you have a habit of squeezing your teeth together during the day?"
5. "Do you ever wake up with a feeling of stiffness or tiredness in your jaws?"
6. "Does it ever hurt when you open, close your mouth or chew?"
7. "Do you ever find that you can't open your mouth wide?"

8. "Do you ever notice that your jaw locks open and you have trouble closing your mouth?"

9. "Do you ever hear any clicking or crackling noises when you open or close your mouth?"

10. "Have you had any injury to your face or jaws?"

11. "Have you undergone any treatment for any problems to do with your teeth or jaws other than fillings?" If the patient was undergoing treatment for dysfunction, the type of treatment (drugs, splint, occlusal equilibration or other) was noted.

If there was a positive reply to questions 2 to 9, the patient was questioned about the time of initial onset of the symptom. The duration (Dur) of the symptomatic state was recorded in months. If the individual giving the positive response had had orthodontic treatment, the onset of symptoms was also recorded in relation to the treatment as follows:

A - prior to orthodontic treatment

B - during treatment

C - after treatment.

Table IV

Examination form: Clinical Examination

Name ______________________

Date ______________________

1. PALP, PAIN

Trap	....	Left ___	Right ___	....
Scm	....	Left ___	Right ___	....
Mass	....	Left ___	Right ___	....
Temp	....	Left ___	Right ___	....
Lat. TMJ	....	Left ___	Right ___	....
Post. TMJ	....	Left ___	Right ___	....
Lat. Pter.	....	Left ___	Right ___	....
Ins. Temp.	....	Left ___	Right ___	....
Med. Pter.	....	Left ___	Right ___	....

2. THIRD MOLARS EXT. No ___ Yes ___ ....

3. ORTHO. EXT.: ______________ ....

4. MISSING TEETH: Ant. ___ Post. ___ CONG: Ant. ___ Post. ___

5. REST. POST. SURF.: ______________ ....

6. ROTAT. POST. 15-45° ___ >45° ___ ....

ANT. 15-45° ___ >45° ___ ....

7. DISPL. > 2 MM.: Ant. ___ Post. ___ ....

8. FACETS: .... No ___ Yes ___ ....

9. X BITE: .... Ant. ___ Post. ___ ....

Funct. ___ Non-funct. ___ ....

10. OVERJET: .... + ___ - ___ ....

11. PROT: .... mm. ___ Pain ___ ....

12. OVERBITE: .... mm. ___ Thirds ___ Open ___ ....

13. MAX. OPEN: .... mm. ___ Pain ___ ....

14. RT. MOLAR: .... III ___ C ___ I ___ C ___ II ___

CUSPID: .... III ___ C ___ I ___ C ___ II ___

15. LT. MOLAR: .... III ___ C ___ I ___ C ___ II ___

CUSPID: .... III ___ C ___ I ___ C ___ II ___

16. RT. LAT.: .... CU ___ GP ___ OTH ___ BAL ___ ....

mm. ___ Pain ___ ....

17. LT. LAT.: .... CU ___ GP ___ OTH ___ BAL ___ ....

mm. ___ Pain ___ ....

18. DORSAL LOCK: ...... No ___ Yes ___ ....

19. RCP-IP: .... No ___ Yes ___ ....

Slide: .... Ant. ___ Lat. ___ Rt. ___ Lt. ___ ....

20. DEVIAT.: .... 2-4 mm. ___ >4 mm. ___ Rt. ___ Lt. ___ ...

21. JERKY MOVT.: ...... No ___ Yes ___ ....

22. SUB LUX __________ DISLOCATION __________ ....

23. CLICK __________ CREP __________ ....

24. SEVERITY MAL. ..... 1 ___ 2 ___ 3 ___ ....

25. SEVERITY DYSF. ..... 1 ___ 2 ___ 3 ___ ....

Table V

Methodology of the Clinical Examination

The form used in recording the information from the clinical examination is shown in Appendix Table IV.

1. The patient was first examined for muscle soreness to palpation. Only a clear statement of sensitivity to pain or an obvious palpable response was recorded as positive for pain. Firm pressure was used and the muscles were examined according to the technique recommended by Solberg (1976). The following muscles were palpated bilaterally: trapezius (Trap.), sternocleidomastoid (Scm.), masseter (Mass.), temporalis (Temp.). The lateral and posterior aspects of the temporomandibular joint (Lat TMJ, Post TMJ) were also examined bilaterally, the latter through the external auditory meatus. The lateral pterygoid (Lat. Pter.), medial pterygoid (Med. Pter.) and insertion of the temporalis (Ins Temp) were examined on one side at a time because of the difficulty of access.

The patient was then placed in the supine position for the remainder of the examination.

2. If the third molars were not present, the patient was asked, "Have you had your wisdom teeth taken out?"
3. Any extractions for orthodontic purposes were noted.
4. Other extracted and congenitally missing teeth were recorded.
5. The number of posterior restored surfaces was noted, excluding those solely on lingual or buccal surfaces.

The following factors were measured according to the guidelines of Grainger (1967): rotations of teeth, displacement of teeth from the general arch form, posterior crossbite, overjet, overbite, and molar relationship.

6. Rotations were estimated as to severity and recorded as being 15 to 45 degrees, or greater than 45 degrees.

7. Teeth displaced from the general arch form were recorded as about 2 mm. displaced, or greater than 2 mm. displaced.

8. Wear facets on teeth were identified initially, but this item was deleted because of difficulty of distinguishing functional from parafunctional faceting.

9. Crossbite was noted as anterior or posterior, the number of teeth in crossbite was recorded, as was a functional mandibular shift because of the crossbite.

10. Overjet was measured from the labial surface of the lower right central incisor to the labial incisal edge of the upper right central incisor.

11. Maximum jaw protrusion was recorded, and any pain on this movement was noted.

12. Overbite was measured in millimeters and crown thirds and impinging overbites were noted.

13. Maximum mouth opening was measured between the incisal edges of upper and lower incisors and any pain on opening was noted.

14.
15. Molar relationship was recorded as Angle Class I, II, or III, or cusp-to-cusp between Class I and II or between Class I and III. If, for orthodontic purposes, two premolar teeth had been

extracted in the upper arch only, the molar relationship was recorded as Class I to avoid categorizing this type as an abnormal occlusion, following the recommendations of Popovich and Thompson (1971).

16. The midline of the lower arch was transferred to the upper arch with a pencil and the patient was requested to move the mandible laterally to the right. At 3 mm. of lateral movement the type of guidance was noted: cuspid guidance (CU), group function (GP) or other (OTH) (such as contact of a single premolar or molar on the working side). Three mm. lateral movement has been used in other studies of occlusal function (Ingervall, 1972). With the mandible in this position, the patient was asked if he was aware of tooth contacts on the balancing (non-working) side. The operator also visually inspected the teeth on the non-working side. Unless the lack of contact was obvious, a piece of shim stock was used to definitively test for balancing contacts. If at 3 mm. lateral excursion there was difficulty in removing the shim stock from between the balancing side teeth, a balancing contact (BAL) was recorded. Maximum lateral movement in millimeters and any pain on movement was noted.

17. The same procedure as in #16 was then carried out to evaluate left lateral excursions.

18. Very deep overbite at or beyond the level of the gingival third of the lower anterior tooth along with minimal overjet (1 mm. or less) was recorded as "dorsal locking" (DORSAL LOCK) if there was no slide in centric of greater than 0.5 mm.

19. The mandible was manipulated into centric relation by the technique of Dawson (1976) and slides from retruded contact position (RCP) to intercuspal position (IP) were recorded according to amount and direction. Measuring the difference in overjet at RCP and IP indicated the amount of antero-posterior slide, and the midline pencil mark was used in a similar way to measure the amount of lateral slide.
20. Lateral deviation (DEVIAT.) was recorded between 2-4 mm. or greater than 4 mm., and to the right or left.
21. By placing the operator's fingers over the TMJ and having the patient open wide, any jerky or asymmetrical condylar movement was noted. (JERKY MOVT.)
22. Subluxation (SUB LUX) (partial dislocation of the condyle easily reduced by the patient) and dislocation (complete dislocation requiring manual manipulation for reduction) were noted.
23. A stethoscope placed over the TMJ was used to record the presence of clicking (CLICK) and/or crepitus (CREP) in one or both joints.
24. A subjective assessment of the state of malocclusion (SEVERITY MAL.) was recorded by the operator:

    1 - no orthodontic treatment required

    2 - moderate malocclusion, treatment optional

    3 - severe malocclusion, treatment mandatory.
25. A subjective assessment of the state of dysfunction (SEVERITY DYSF.) was recorded by the operator:

    1 - no dysfunction, or clicking as the only dysfunction sign

    2 - moderate dysfunction, adequate ability to function possible

    3 - severe dysfunction, normal functioning not possible.

Table VI

Calculation of the Clinical Dysfunction Index based on the evaluation of five common clinical signs of dysfunction

		Score
A. Sign:	Impaired range of movement/mobility	
Criteria:	*Maximum mouth opening > 40 mm. and Maximum lateral jaw excursions > 7 mm. and Maximum protrusive jaw movements > 7 mm.	0
	*Maximum mouth opening 30-39 mm. and/or Maximum lateral jaw excursions 4-6 mm. and/or Maximum protrusive jaw movements 4-6 mm.	1
	*Maximum mouth opening < 30 mm. and/or Maximum lateral jaw excursions < 4 mm. and/or Maximum protrusive jaw movements < 4 mm.	5
B. Sign:	Impaired TMJ function	
Criteria:	Smooth movement without TMJ sounds and deviation on opening or closing movements < 2 mm.	0
	TMJ sounds in one or both joints and/or deviation > 2 mm. on opening or closing movements	1
	Subluxation and/or dislocation of the TMJ	5
C. Sign:	Masticatory muscle pain	
Criteria:	No tenderness to palpation in masticatory muscles	0
	Tenderness to palpation in 1-3 palpation sites	1
	Tenderness to palpation in 4 or more palpation sites	5
D. Sign:	Temporomandibular joint pain	
Criteria:	No tenderness to palpation	0
	Tenderness to palpation laterally	1
	Tenderness to palpation posteriorly	5
E. Sign:	Pain on movement of the mandible	
Criteria:	No pain on movement	0
	Pain on 1 movement	1
	Pain on 2 or more movements	5
F.	Sum A + B + C + D + E = dysfunction score (0-25 points)	

*sum of maximum mandibular opening and overbite

Table VII

Distribution of the entire sample by
cardinal symptoms and signs

	Symptoms		Signs	
	Number	Percent	Number	Percent
No Symptoms/Signs	160	42	120	32
Joint Sounds only	65	18	57	15
Pain only	55	15	27	7
Limited Movement only	7	2	54	15
Joint Sounds + pain	55	15	31	8
Joint Sounds + Limited Movement	6	2	36	10
Pain + Limited Movement	5	1	24	7
Joint Sounds + Pain + Limited Movement	18	5	22	6
	371	100	371	100

Table VIII

Incidence and percentages of primary and secondary dysfunction factors in the clinical examination for the entire sample

Primary Factors	Number (n=371)	Percent
Muscle pain:		
Trapezius	35	9.4
Sternocleidomastoid	31	8.4
Masseter	16	4.3
Temporalis	17	4.6
Lateral Pterygoid	50	13.5
Insertion Temporalis	16	4.3
Medial Pterygoid	23	6.2
TMJ pain:		
Lateral TMJ	22	5.9
Posterior TMJ	16	4.3
Movement pain:		
Left lateral	6	1.6
Right lateral	10	2.7
Maximum opening	18	4.9
Subluxation	4	1.1
Dislocation	0	0
Clicking	118	31.8
Crepitus	38	10.2
Secondary Factors		
Jaw deviation	43	11.6
Jerky movements	43	11.6

Table IX

The incidence and percentages (in brackets) of primary and secondary dysfunction factors in the anamnestic examination for control and treated groups and the tests of significance

	Control Group (n=201)	Treated Group (n-170)	Significance
Primary Factors			
TMJ and ear pain	50 (24.9)	15 (8.8)	***
Face pain	29 (14.4)	(10)	NS
Temple pain	33 (16.4)	15 (8.8)	*
Movement pain	36 (17.9)	15 (8.8)	**
Limited movement	27 (13.4)	9 (5.3)	**
Subluxation/dislocation	22 (10.9)	15 (8.8)	NS
Joint sounds	78 (38.8)	66 (38.8)	NS
Secondary Factors			
Headache	43 (21.4)	41 (24.1)	NS
Neck pain	85 (42.3)	45 (26.5)	**
Back pain	70 (34.8)	37 (21.8)	**
Body joint pain	33 (16.4)	11 (6.5)	**
Jaw fatigue	29 (14.4)	18 (10.6)	NS
Trauma history	27 (13.4)	23 (13.5)	NS
Previous treatment	3 (1.5)	0 0	NS
Bruxism	49 (24.4)	32 (18.8)	NS

NS not significant

* $p < .05$

** $p < .01$

*** $p < .001$

Table X

A comparison of index values between control and treated groups and the tests of significance

	Control Group (n=201)		Treated Group (n=170)		
	Number	Percent	Number	Percent	Significance
ADI - 1	83	41.8	82	48.2	
- 2	34	16.9	45	26.5	**
- 3	83	41.3	43	25.3	
CDI - 1	118	58.7	112	65.9	
- 2	57	28.4	32	18.8	NS
- 3	26	12.9	26	15.3	
CSI - 1	132	65.7	101	59.5	
- 2	52	25.9	47	27.6	NS
- 3	17	8.5	22	12.9	
AII - 1	90	44.8	111	65.3	
- 2	41	20.4	15	8.8	***
- 3	70	34.8	44	25.9	
+SAM - 1	74	36.8	149	87.6	
- 2	69	34.3	18	10.6	***
- 3	58	28.9	3	1.8	
++SAD - 1	178	88.6	143	84.1	NS
- 2	23	11.4	27	15.9	

NS not significant
** $p<.01$
*** $p<.001$
\+ subjective assessment of malocclusion
++ subjective assessment of dysfunction

Table XI

The incidence and percentages (in brackets) of primary and secondary dysfunction factors in the clinical examination for treated and control groups and the tests of significance

	Control Group (n=201)	Treated Group (n=170)	Significance
Primary Factors			
Muscle pain:			
Trapezius	23 (11.4)	1 (7.1)	NS
Sternocleidomastoid	17 (8.5)	14 (8.2)	NS
Masseter	6 (3.0)	10 (5.9)	NS
Temporalis	8 (4.0)	9 (5.3)	NS
Lateral Pterygoid	31 (15.4)	19 (11.9)	NS
Insertion Temporalis	8 (4.0)	8 (4.7)	NS
Medial Pterygoid	12 (6.0)	11 (6.5)	NS
TMJ pain:			
Lateral TMJ	11 (5.5)	11 (6.5)	NS
Posterior TMJ	5 (2.5)	11 (6.5)	NS
Movement pain:			
Protrusive	10 (5.0)	6 (3.5)	
Left Lateral	3 (1.5)	3 (1.8)	NS
Right Lateral	6 (3.0)	4 (2.4)	NS
Maximum opening	12 (6.0)	6 (3.5)	NS
Subluxation	0 (0)	4 (2.4)	NS
Dislocation	0 (0)	0 (0)	NS
Clicking	63 (31.3)	55 (32.4)	NS
Crepitus	18 (9.0)	20 (11.8)	NS
Secondary Factors			
Jaw deviation	18 (9.0)	25 (14.7)	NS
Jerky movements	17 (8.5)	26 (17.7)	NS

NS not significant

Table XII

Mean values (in mm.) of primary dysfunction factors in the clinical examination for control and treated groups and the tests of significance

	Control Group (n=201)	Treated Group (n=170)	Significance
+Maximum opening	54.9	51.8	NS
Maximum right lateral	9.5	9.3	NS
Maximum left lateral	9.1	8.8	NS
Maximum protrusion	8.0	8.8	***

\+ sum of maximum mandibular opening and overbite

Table XIII

Mean values of primary and secondary factors in the occlusal examination for control and treated groups and the tests of significance

	Control Group (n=201)	Treated Group (n=170)	Significance
Primary Factors			
Missing teeth	0.39	0.02	***
Overbite (mm.)	5.40	3.50	NS
Overjet (mm.)	4.60	2.80	*
Secondary Factor			
Restored posterior surfaces	5.40	6.40	*

NS not significant

* $p<.05$

*** $p<.001$

\+ sum of maximum mandibular opening and overbite

Table XIV

Incidence and percentages (in brackets) of secondary factors in the occlusal examination for control and treated groups and the tests of significance

	Control Group (n=201)	Treated Group (n=170)	Significance
Dorsal locking	18 (9.0)	2 (1.2)	**
Third molar extraction	13 (6.5)	23 (13.5)	*

* p<.05

** p<.01

Table XV

Mean index values for the 7 different subgroups in the treated and control groups

	Indices				
	ADI	CDI	TPI	CSI	AII
Treated Group					
T-CLINIC	.78	1.99	2.15	.98	1.31
T-HS1	.30	1.80	2.19	.70	1.30
T-UofW	1.12	2.24	3.58	.94	2.41
Control Group					
C-CLINIC	1.00	2.00	8.12	.65	1.71
C-HS1	.71	1.55	6.01	.68	1.79
C-HS2	.93	2.06	5.14	.94	1.94
C-UofW	1.43	2.17	4.97	.23	2.34

Table XVI

Mean TPI scores for symptom-free and symptomatic subjects in the control group for primary and secondary factors in the anamnestic examination and significance of the difference

	Symptom-Free	Symptomatic	Significance
Primary Factors			
TMJ and ear pain	6.26	6.38	NS
Face pain	6.45	5.29	NS
Temple pain	6.23	6.58	NS
Movement pain	6.28	6.29	NS
Limited movement	6.28	6.37	NS
Joint sounds	6.19	6.44	NS
Secondary Factors			
Headache	6.09	7.01	NS
Neck pain	6.28	6.29	NS
Back pain	6.02	6.79	NS
Body joint pain	6.23	6.58	NS
Jaw fatigue	6.38	5.71	NS
Bruxism	6.23	6.46	NS

NS not significant

Table XVII

Mean TPI scores for symptom-free and symptomatic subjects in the control group for primary and secondary factors in the clinical examination and significance of the difference

	Symptom-Free	Symptomatic	Significance
Primary Factors			
Muscle pain:			
Sternocleidomastoid	6.30	6.08	NS
Masseter	6.31	5.48	NS
Temporalis	6.32	5.57	NS
Lateral Pterygoid	6.19	6.80	NS
Insertion Temporalis	6.30	5.87	NS
Medial Pterygoid	6.35	5.22	NS
TMJ pain:			
Lateral	6.39	4.53	NS
Posterior	6.24	7.95	NS
Movement pain:			
Protrusion	6.17	8.14	NS
Left lateral	6.34	3.77	NS
Right lateral	6.22	8.73	NS
Maximum opening	6.29	6.61	NS
Clicking	6.53	5.74	NS
Crepitus	6.29	8.27	*
Secondary Factors			
Jaw deviation	6.19	7.26	NS
Jerky movement	5.92	6.56	NS

NS not significant

* $p<.05$

Table XVIII

Mean TPI scores in the control group for five indices and the tests of significance

	TPI Score	Significance
ADI-1	5.9	NS
-2	6.4	
-3	6.5	
CDI-1	6.1	NS
-2	6.5	
-3	6.6	
CSI-1	6.2	NS
-2	6.3	
-3	7.3	
AII-1	5.9	NS
-2	6.5	
-3	6.7	
+SAD-1	6.2	NS
-2	6.7	

NS not significant

\+ subjective assessment of dysfunction

Table XIX

Percentage of associated dysfunction factors in the various ADI and CDI value categories and the test of significance. Entire sample used

	ADI Values				CDI Values			
	1	2	3	Sig.	1	2	3	Sig.
Headache	11.4	15.2	42.1	***	15.2	30.3	42.3	***
Neck pain	21.7	44.3	46.8	***	27.4	43.8	53.8	***
Back pain	18.7	26.6	43.7	***	24.3	39.3	30.8	*
Body joint pain	9.6	10.1	15.9	NS	9.1	15.7	17.3	NS
Jaw fatigue	0.0	21.5	23.8	***	9.1	19.1	17.3	*
Trauma history	8.4	19.0	16.7	*	10.9	19.1	15.4	NS
Previous treatment	0.6	0.0	1.6	NS	1.3	0.0	0.0	NS
Bruxism	16.9	29.1	23.8	NS	20.0	24.7	25.0	NS

NS not significant

* $p<.05$

*** $p<.001$

Table XX

Percentage of primary and secondary dysfunction factors in the anamnestic examination for the three age groups and the tests of significance

	Age Group			
	12-15 (n=101)	16-19 (n=157)	20-30 (n=113)	Significance
Primary Factors				
TMJ and ear pain	16.8	15.3	21.2	NS
Face pain	5.9	12.7	17.7	*
Movement pain	12.9	12.1	16.8	NS
Limited opening	8.9	8.3	12.4	NS
Subluxation/dislocation	2.0	0	1.8	NS
Joint sounds	31.7	40.1	43.4	NS
Secondary Factors				
Headache	20.8	23.6	23.0	NS
Neck pain	28.7	31.2	46.0	**
Back pain	21.8	29.3	34.5	NS
Body joint pain	6.9	12.1	15.9	NS
Jaw fatigue	7.9	11.5	18.6	*
Trauma history	6.9	18.5	12.4	NS

NS not significant

* $p<.05$

** $p<.01$

Table XXI

Percentage of primary and secondary dysfunction factors in the clinical examination for the three age groups and the tests of significance

	Age Group			
	12-15 (n=101)	16-19 (n=157)	20-30 (n=113)	Significance
Primary Factors				
Muscle pain:				
Trapezius	6.9	9.6	4.5	NS
Sternocleidomastoid	5.0	8.9	10.6	NS
Masseter	4.0	3.2	6.2	NS
Temporalis	3.0	3.8	7.1	NS
Lateral Pterygoid	8.9	15.9	14.2	NS
TMJ pain:				
Lateral	4.0	1.9	13.3	***
Posterior	3.0	4.5	5.3	NS
Movement:				
Protrusive	5.0	3.8	4.4	NS
Left lateral	3.0	1.9	0.0	NS
Right lateral	4.0	3.2	.9	NS
Maximum opening	5.9	3.8	5.4	NS
Subluxation	2.0	0.0	1.8	NS
Clicking	20.8	35.7	36.3	*
Crepitus	3.0	12.7	13.3	**
Secondary Factors				
Jaw deviation	10.9	10.8	13.3	NS
Jerky movements	2.4	11.3	25.0	***

NS not significant

* $p<.05$

** $p<.01$

*** $p<.001$

Table XXII

Mean values of six factors from the anamnestic, clinical and occlusal examinations for the three age groups and the tests of significance

	Age Group			
	12-15 (n=101)	16-19 (n=157)	20-30 (n=113)	Significance
Anamnestic Examination				
Months since debanding	14.7	34.2	48.3	***
Clinical Examination				
+Maximum opening	53.4	53.7	53.0	NS
Maximum right lateral	9.9	9.4	9.0	NS
Maximum left lateral	9.3	9.3	8.2	**
Maximum protrusion	8.8	8.3	8.1	NS
Occlusal Examination				
Missing teeth	0.2	0.2	0.3	NS

NS not significant
** $p<.01$
*** $p<.001$
+ sum of maximum mandibular opening and overbite

Table XXIII

Percentages of four factors from the occlusal and functional examinations for the three age groups and the test of significance

	Age Group			
	12-15 (n=101)	16-19 (n=157)	20-30 (n=113)	Significance
Occlusal Examination				
Dorsal locking	9.9	2.5	5.3	*
Third molar extraction	3.0	7.6	18.6	***
Functional Examination				
Point centric	22.8	22.3	23.9	NS
Balancing contacts	24.1	42.0	33.9	NS

NS not significant
* $p<.05$
*** $p<.001$

Table XXIV

Percentage of primary and secondary dysfunction factors in the anamnestic examination for males and females and the tests of significance

	Males (n=124)	Females (n=247)	Significance
Primary Factors			
TMJ pain	21.0	15.8	NS
Face pain	8.1	14.6	NS
Movement pain	13.7	13.8	NS
Limited opening	9.7	9.7	NS
Subluxation/dislocation	.8	1.2	NS
Joint sounds	32.3	42.1	NS
Secondary Factors			
Headache	12.1	27.9	***
Neck pain	31.5	36.8	NS
Back pain	28.2	29.1	NS
Body joint pain	13.7	10.9	NS
Jaw fatigue	14.5	11.7	NS
Trauma history	22.6	8.9	**

NS not significant

** $p<.01$

*** $p<.001$

Table XXV

Percentage of primary and secondary dysfunction factors in the clinical examination for the three age groups and the tests of significant difference

	Males (n=124)	Females (n=247)	Significance
Primary Factors			
Muscle pain:			
Trapezius	6.5	10.9	NS
Sternocleidomastoid	7.3	8.9	NS
Masseter	2.4	5.3	NS
Temporalis	3.2	5.3	NS
Lateral Pterygoid	8.9	15.8	NS
TMJ pain:			
Lateral	6.5	5.7	NS
Posterior	3.4	4.9	NS
Movement pain:			
Protrusive	1.6	5.7	NS
Left lateral	1.6	1.6	NS
Right lateral	2.4	2.8	NS
Maximum opening	4.8	4.9	NS
Subluxation/dislocation	0.8	1.2	NS
Clicking	21.8	36.8	**
Crepitus	14.5	8.1	NS
Secondary Factors			
Jaw deviation	14.5	10.1	NS
Jerky movements	14.2	12.7	NS

NS not significant

** p<.01

Table XXVI

Mean values of six factors from the anamnestic, clinical and occlusal examinations for males and females and the tests of significance

	Male (n=124)	Female (n=247)	Significance
Anamnestic Examination			
Months since debanding	36.6	35.7	NS
Clinical Examination			
+Maximum opening	56.1	52.0	***
Maximum right lateral	9.9	9.2	*
Maximum left lateral	9.2	8.8	NS
Maximum protrusion	8.4	8.3	NS
Occlusal Examination			
Missing teeth	0.2	0.2	NS

NS not significant
* $p<.05$
*** $p<.001$
\+ sum of maximum mandibular opening and overbite

Table XXVII

Percentage of four factors from the occlusal and functional examinations for males and females and the test of significance

	Male (n=124)	Female (n=247)	Significance
Occlusal Examination			
Dorsal locking	5.2	5.3	NS
Third molar extraction	4.8	12.1	*
Functional Examination			
Point centric	20.2	24.3	NS
Balancing contacts	27.4	31.6	NS

NS not significant
* $p<.05$

GLOSSARY OF TERMS

Centric occlusion. The intermaxillary relationship when the teeth are in a position of maximum intercuspation.

Centric relation. The position of the mandible with the condyle in its most superior position.

Centric slides. The movement of the mandible between RCP and IP.

IP. Intercuspal position. Synonymous with centric occlusion.

Point centric. A co-incident position of RCP and IP.

RCP. Retruded contact position. The contact position of the teeth with the mandible in centric relation.