OCCLUSAL CONSIDERATIONS IN BEGG ORTHODONTIC THERAPY

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DEDICATION

This thesis is dedicated to my parents, Nancy and Fred, for their continuing warm-hearted concern and support, to my wife, Ellen, for her never-ending patience and love, and to my children, Renée and Daniel, for providing me with the motivation to do better.

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QUOTATION FROM E.H.ANGLE

READ BEFORE THE ACADEMY OF STOMATOLOGY

MARCH 1, 1904

"For were the teeth not created solely for occlusion? Study their shapes, study their forms and proportions, examine them microscopically, study their positions and periods of eruption, and the very structure and arrangement of that wonderful membrane that holds them in position, and, too, that peculiar structure, the alveolar process, that comes at their bidding and vanishes with their going - all, all point to occlusion and the one grand object of its function."

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CHAPTER 1

Introduction

1. INTRODUCTION

Throughout the development of the speciality of orthodontics there have been individuals who have urged orthodontists to seek the total benefits for patients that orthodontics is capable of providing (Perry 1976). According to Perry, too often their pleas were drowned by the arguments of those interested in aesthetics and static analysis of the dental occlusion. More frequently today, orthodontists are "feeling the heat" of their generalists, colleagues and other specialities who believe that they have disavowed their responsibility to function and long-term stomatognathic health. The road to understanding of occlusion is difficult, and may be endless, but is not occlusion what orthodontics and dentistry are all about? (Wood 1977) This thesis embarks upon this road in an attempt to answer the criticism that orthodontists face regarding occlusal concepts.

Graber (1966) said that, "unless we recognize and discuss the problems and limitations of orthodontic treatment among ourselves, unless we present the limitations and disadvantages of a particular technique as well as the recommendations for its use, and unless we keep our patients under observation longer, and observe the status of the stomatognathic system in its biological continuum, we cannot expect a realistic and objective appreciation of our efforts by the public or by most general dentists. A major consideration here must be our cult-and-system-orientated orthodontic philosophies and our persistent tendency to show only the good cases, and even those before they have had a chance to undergo those insidious posttreatment changes. A man is a Johnson man, a Tweed man, a Begg man, an edgewise man, or a renegade if he has left one camp and joined another. In our competitive society, it would be heresy to the cause to admit anything that might be construed as shortcomings of our particular orthodontic technique".

It is a matter of primary concern to ensure that the long term effects of treatment should confer a lasting benefit

on our patients (Vig 1975). Awareness of the biological principles and the recognition of their clinical significance is, therefore, no longer simply an academic preoccupation. In this study I hope to stimulate the critical re-evaluations, discussions and controversy that fuel clinical scholarship on the subject of occlusion in orthodontics. In this way it is hoped that communication between "occlusionists" and orthodontists will take place, in an attempt to comprehend, and respect, each other's point of view and limitations, and so that common ground for agreement can be reached.

The present study was a preliminary, descriptive, epidemiological investigation of a group of orthodontic patients treated by the Begg technique, and assessed after an initial period of "functional settling" had been allowed for. The aim of the study was firstly to observe the presence or absence of occlusal disharmonies, and secondly to examine whether a clinical correlation could be found between "form" and "function", which may help the orthodontist in the achievement of treatment objectives, as well as providing areas for future research.

CHAPTER 2

The Physiology of Occlusion

2.1 TISSUES PARTICIPATING IN OCCLUSION

There is still much controversy regarding mandibular muscle function, proprioception in the head and neck, temporo-mandibular joint function, and somatosensory innervation of the stomatognathic system (Mahan 1979b). However, a brief review of some aspects of anatomy and physiology which are pertinent to the orthodontist's appreciation of "functional" occlusion is necessary for the present discussion.

2.11 The temporomandibular joints

The temporomandibular joints are combined ginglymus (hinge) and gliding joints (Bauer and Gutowski 1976). The articular disc is situated between the cylindrical condyle and the glenoid cavity. The disc separates the joint into two functional regions. Pure hinge motions take place in the lower section, between the cylinder and the articular disc. Sliding motions take place in the upper section, between the disc and the glenoid cavity. The motions of the temporomandibular joints, and thus the motions of the mandible, are limited by ligaments (the lateral, spheno-mandibular, and temporomandibular ligaments) and the fibrous joint capsules.

Despite the number of clinical and experimental studies, no universal agreement has been reached regarding the "potential for adaptation" in response to an alteration of the structural or functional environment by means of growth and/or remodeling of the temporomandibular joints (McNamara 1979). This is an important consideration in assessing what effect occlusal disharmony may have on the temporomandibular joints. McNamara says that there is little experimental evidence demonstrating that any significant adaptations can occur in the adult temporo-mandibular joints, and pathological changes have been reported to occur in some instances. An exception to this may be changes following mandibular resections which produce changed articular relationship, rarely with evidence of post-surgical pathology (Godfrey 1981). In contrast, other

studies have shown that the temporomandibular joint region, particularly the mandibular condyle of young, growing animals, can be a primary site of craniofacial adaptation to altered occlusal function (Sturtzmann and Petrovic 1979).

The subarticular cartilagenous region of the condyle is divided into two general layers - a prechondroblastic zone and a chondroblastic zone (McNamara and Carlson 1979). The prechondroblastic zone lies immediately inferior to the articular layer and is continuous with the inner (osteogenic) portion of the periosteum. It is the major site of chondrocytic proliferation. The chondroblastic zone contains the maturing chondrocytes which eventually hypertrophy and form the structure necessary for osteogenesis along the endosteal surface of the condyle. Stutzmann and Petrovic (1979) suggest the existence of an intrinsic regulatory mechanism of the condylar cartilage growth rate. They say that there is a "negative feedback signal" originating from the proximal part of the chondroblastic zone and exerting a restraining effect on the prechondroblastic multiplication rate.

According to Moss and Rankow (1968), the associated facial viscera, ligaments and muscles of the temporomandibular joint comprise the matrix required to carry out the function of mastication and deglutition. They state that the condylar process exists only as a skeletal unit supporting this functional matrix, and its growth is secondary and adaptive to changes in the functional matrix. Moss (1975) emphasizes that there is every reason to believe that the temporomandibular joint is significantly responsive to a dynamically altering environment, and capable of significant morphological adaptation. Levy (1975, 1976) agrees with this concept.

Mongini (1981) claims that remodeling of the temporomandibular joint is a functional adaptive process. Degenerative lesions, he says, are superimposed on remodeling as a consequence of long-term dysfunction. Mongini (1977) says that extensive remodeling of the temporomandibular joint takes place throughout life. The degree of remodeling and the new shape

imposed on the condyles, he says, are closely related to changes in the dentition, due to partial loss of teeth or dental abrasion, and also the position of the condyles in centric occlusion. Mongini (1980) says that the reshaping of the condyle due to bone remodeling may take place after occlusal therapy (occlusal splints, selective grinding, prosthodontic rehabilitation, orthodontic treatment). The reshaping, he says, affects the condyles, which were previously flattened as a result of occlusal alteration. The new shape tends to be more rounded.

Weinberg (1979) says that temporomandibular joint remodeling has not been completely investigated, and has been confused with physiological adaptation. Temporomandibular joint remodeling is a reshaping, or reformation, of the anatomic and histologic form, in response to functional demands. The objective of this response is to alter physical form to maintain normal function. Weinberg says that definite distinctions should be made between experimental evidence in young growing animals and those in adult animals. In adults, alterations in mandibular position will not produce a "corrective remodeling" of the temporomandibular joint according to Weinberg, and pathologic changes can take place. Weinberg further stresses that physiologic adaptation, accommodation, and adjustment in function within the temporomandibular joint should not be confused with histologic condylar "remodeling". He believes that, in temporomandibular joint adaptation, there is no significant alteration of physical form; however, there is a modification in "normal" joint function. Joint dysfunction, or pathologic changes, develop when this "adaptive ability" is exceeded. Thus, Weinberg says that temporomandibular joint physiologic adaptation occurs where the joint does not remodel, but tolerates long-standing condylar displacements with minimal or subclinical symptoms.

Obviously, the question remains: does the temporomandibular joint "adaptation" concern joint function as such, or function of the jaw moving musculature?

2.12 The musculature

Physiologically, the mandible is held in a sling of cradling musculature and ligaments (Levy 1975). The muscles are the temporalis, masseter, medial and lateral pterygoid, digastric, and suprahyoid and infrahyoid muscles (Bauer and Gutowski 1976). The mandible can be maintained in various positions with and without tooth contacts. Mastication and swallowing involve some of the tongue and facial muscles as well, including the buccinators and orbicularis oris.

Matthews (1975) says that during the closing phase of mastication, the temporalis muscle on the working side is the first to become active, followed by both massters and the temporalis of the non-working or balancing side. During an incisive movement the masseter and medial pterygoid muscles are the first to become active. The lateral pterygoid muscle produces the anterior sliding movement in the temporomandibular joint, and is active during protrusive and opening movements, although it is not strictly a depressor of the mandible (Matthews 1975). Contraction of the superior head of the lateral pterygoid serves to stabilize the temporomandibular joint meniscus on the articular eminence. The suprahyoid muscles (digastric, mylohyoid, geniohyoid) produce jaw opening; but for these to be effective in depressing the mandible, the hyoid bone must be stabilized with respect to the base of the skull, and this is achieved by contraction of the infrahyoid muscles and stylohyoid. The suprahyoid muscles contract against a stabilized mandible to elevate the hyoid bone during swallowing (Matthews 1975).

Interspersed within each skeletal muscle are tiny nerve endings called muscle spindles, which can detect even the slightest contraction or loading of a muscle. The spindles monitor both the contraction of the mover muscle and the stretch of its opponent. The release of the antagonistic muscle is directed via nerve pathways to coincide with both the intensity and the speed of the contracting muscles (Dawson 1974).

2.13 The tooth supporting apparatus

Teeth are stressed through contact with antagonists, a food bolus and other solids, during swallowing and "empty" contacts, and through pressure exerted by the tongue, cheeks and lips. These forces are transferred through the periodontal fibres from cementum to the alveolar bone in the form of pressure or stretching. Axial strains are functionally preferable (Bauer and Gutowski 1976).

According to Matthews (1975), if the bite is raised on one tooth, that tooth is subjected to increased occlusal loads, although there is some evidence that the total tension developed by the elevator muscles may be reduced, presumably as a result of the effects of increased stimulation of periodontal mechanoreceptors around the high tooth and its opponent. Matthews says that a maximum biting force of 50kg can be recorded in the first molar region and 10kg in the incisor region, although these measurements can be increased with practice.

The functions of the periodontal ligament are formative, supportive, protective, sensory, and nutritive (Sicher 1966). The formative function is fulfilled by the cementoblasts and the osteoblasts, which are essential in building cementum and bone, and the fibroblasts, which form the fibres of the ligament. The supportive function is that of maintaining the relation of the tooth to the surrounding hard and soft tissues. This is achieved by connective tissue fibres that comprise the bulk of the ligament. The bundles of collagenous fibres are so arranged that they can be divided into the following ligaments:

A. The fibres of the gingival ligament attach the free and attached gingiva to the cementum.

B. The transseptal, or interdental, ligaments connect adjacent teeth. The ligaments, but not the single fibres, run from the cementum of one tooth over the crest of the alveolus to the cementum of the neighbouring tooth.

C. The alveolodental ligament attaches the tooth to the bone of the alveolus. It consists of five groups of bundles:

alveolar crest group, horizontal group, oblique group, apical group and interradicular group.

Thus, the arrangement of the fibre bundles in the different groups is well adapted to fulfill the supportive functions of the periodontal ligament. The sensory and nutritive functions are carried out by the nerves and blood vessels in the periodontal ligament.

The alveolar bone which forms the inner wall of the socket, consists partly of lamellated and partly of bundle bone (Sicher 1966). Bundle bone is that bone in which the principal fibres of the periodontal ligament are anchored. The bundles of the principal fibres continue into the bone as Sharpey's fibres.

2.14 The central and peripheral nervous systems

The control of jaw movement in function depends on a combination of passive or non-reflex occlusal guidances, and active or reflex influences. It has been found that tooth guidance in the absence of reflex muscle changes occurs in jaw closure from eccentric to intercuspal position, and that canine guidance without reflex muscle changes can be responsible for jaw movement into retruded intercuspal position (Klineberg 1978). Active or reflex contributions altering muscle activity may arise from the mechanoreceptors located in and around teeth, joints, muscles, mucosa, periosteum and skin, which influence muscle spindles (peripheral reflex mechanisms), and there are also influences from the brain stem (particularly the reticular formation) and higher brain centres on alpha and fusimotoneurons, which influence muscle spindles as well (Klineberg 1978).

The functional angle of occlusion is the angle formed by the teeth as the jaw moves into and from intercuspal position in function (Klineberg 1980b). Klineberg (1980a) says that the apex of the functional angle of occlusion is controlled by passive tooth guidances from the point of initial tooth contact, through intercuspal position to

the point of departure from tooth contact, so that posterior tooth cusp height and anterior tooth arrangement are influential constraints over this area of jaw movement. Also, the reproducibility of the functional angle of occlusion is apparent over a greater distance than tooth guidance. The precision of the functional angle of occlusion thus appears to be dependent upon pre-programmed motor control, to provide definitive guidance to modulate the approach angle and velocity of jaw movement. Klineberg(1980a) says that such programmed motor control is a learned function that accompanies tooth eruption and orientation, and harmonizes with individual occlusal form.

Ontogenetically, it is still not clear whether the postnatal expression of chewing in humans utilizes neuromuscular mechanisms already existing for the programmed movements associated with motor behaviours such as sucking, or whether entirely new neural mechanisms are developed, triggered, for example, by the eruption of teeth (Dubner, Sessle and Storey 1978). They say that, although neural elements inherent in jaw reflexes may be utilized in chewing, at least the basic cyclical pattern of chewing, or rhythmical jaw opening and closing (and possibly related automatic tongue and facial activity), is generated by a central neural program. It can probably function independent of sensory support, but it is unlikely that it does function normally without utilizing sensory information. Dubner, Sessle and Storey (1978) claim that under certain conditions sensory feedback from the dentition alters mandibular movement patterns in chewing. Conditions favouring feedback are heavy forces, nonaxial forces, lowering of thresholds of receptors, short roots, chewing side, and central effects. They say that if the stimulus is mild, a response in movement pattern may not occur immediately. Where the above conditions do not prevail, mastication proceeds without any response to feedback from the dentition.

2.2 MOVEMENTS AND POSITIONS OF THE MANDIBLE

2.21 Sagittal plane

Since Posselt showed that border movements of the mandible are reproducible, and all other movements take place within the framework of the border movements, it appears logical to start the description of mandibular movements with border movements (Ramfjord and Ash 1971). The border movements of the mandible, recorded in the sagittal plane, are shown in Figure 1. It can be seen that the rest position lies on the path of habitual opening and closing, and not on the path of terminal hinge movement. In other words, the rest position is an intra-border one, in which the condyles are not fully seated in their fossae (Behrend 1973).

2.22 Horizontal plane

The border movements for the incisor point can be traced by a gothic arch or Gysi tracing in the horizontal plane (Ramfjord and Ash 1971). This can be seen in Figure 2. In lateral movements from centric closure, the condyle on the laterotrusive side appears to rotate with a slight lateral shift in the direction of the movement (Ramfjord and Ash 1971). The lateral shift or bodily lateral movement of the mandible, during lateral jaw movement, is called the Bennett movement, and has immediate and progressive components. Figure 3 shows right lateral movement of the mandible in the horizontal plane.

2.23 Frontal plane

The patterns of jaw movements recorded in the frontal plane vary greatly with the type of occlusal contact relations. With "excellent" occlusions and with uninhibited masticatory movements, as seen in Australian aborigines, the masticatory cycle has a fairly uniform, wide, oval form; the cycle is wider and more regular than found in subjects of European origin (Ramfjord and Ash 1971).

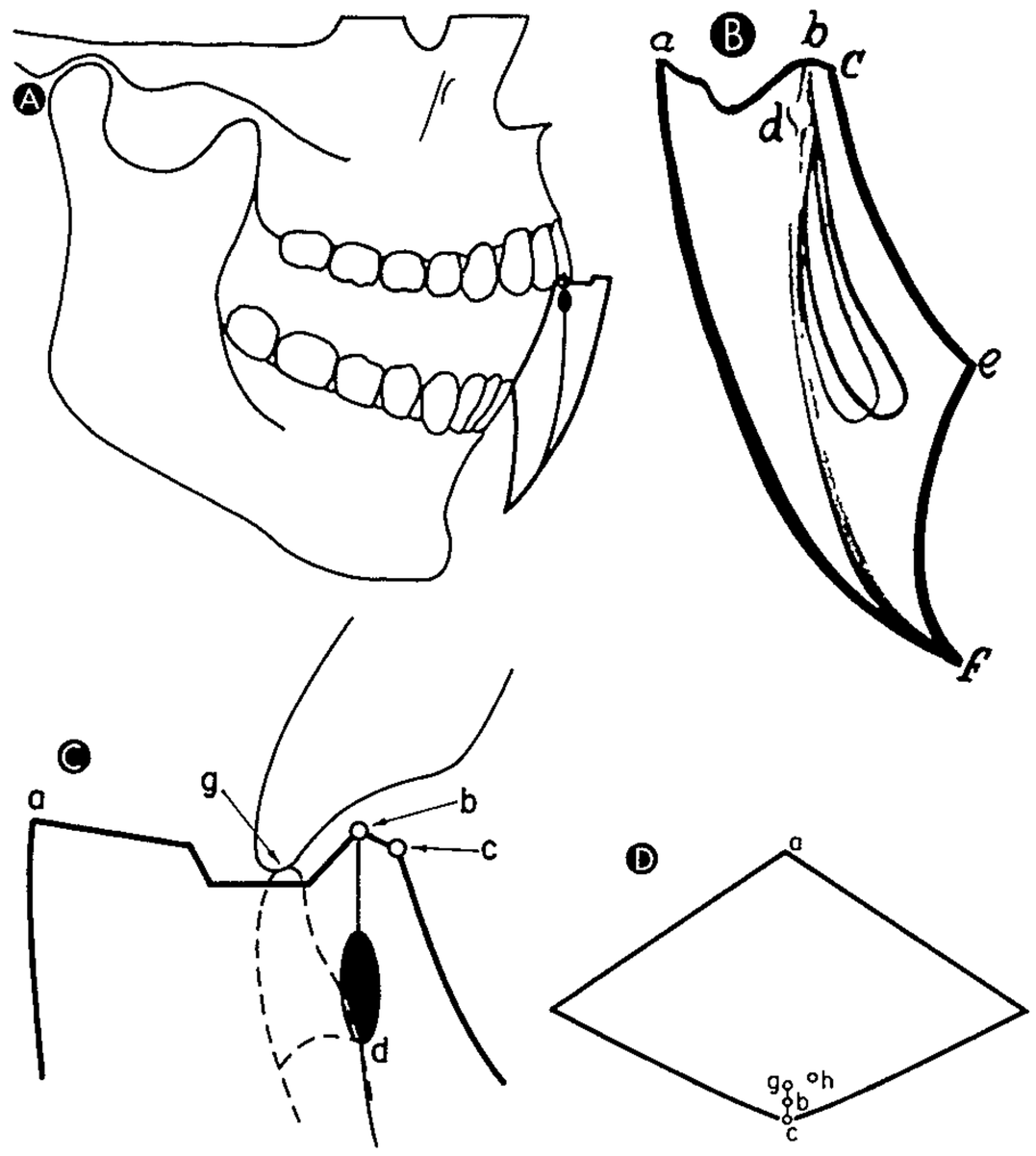

FIGURE 1. A. Border movements of the mandible as recorded in a sagittal plane
B. The envelope of jaw movements
C. An enlargement of the occlusal portion of the envelope of jaw movements
D. A cross section of the envelope of jaw movements
(From: Moyers 1973)

* See next page for code

CODE FOR FIGURE 1:

a. The most protruded occlusal position

b. The median occlusal position

c. The most retruded occlusal position

d. The postural area of the mandible

e. The position at which the condyles return to the glenoid fossae

f. The extreme open position of the mandible

f-a. The protrusive path of opening and closing

f-d-b. The reflex path of jaw closure

f-e-c. The most retruded path of jaw closure

g. Eccentric occlusal position (no lateral deviation)

h. Eccentric occlusal position (lateral deviation)

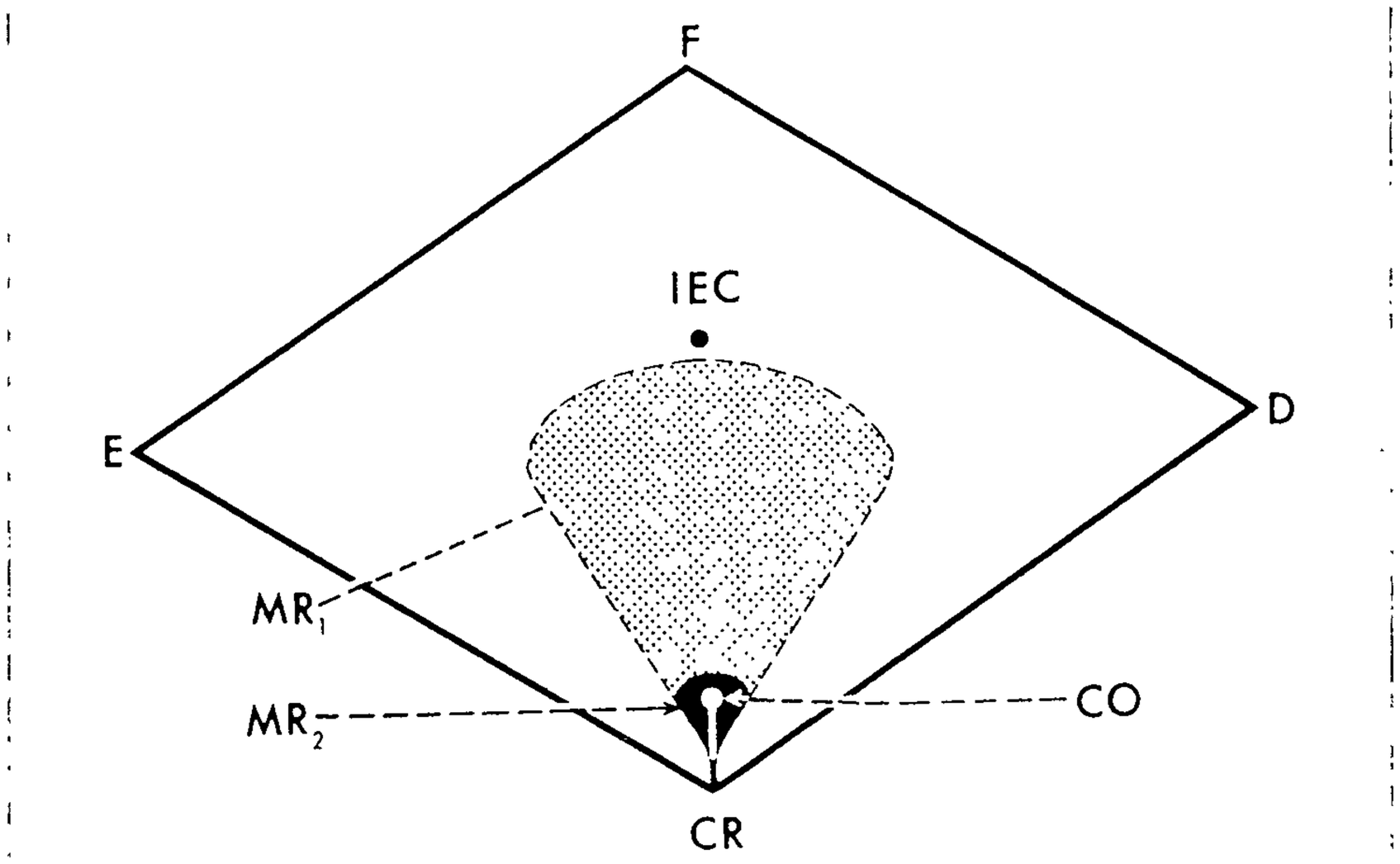

FIGURE 2. Border movements of the mandible in the horizontal plane.

The incisal point is at CR when the condyles are in centric relation, and at point CO when the teeth are in centric occlusion. The small dark area MR2 is the approximate region of function during the latter stages of mastication. The larger stippled area MR1, extending to IEC (incisal edge contact), is the approximate region of function in earlier stages of mastication.

(From: Ramfjord and Ash 1971)

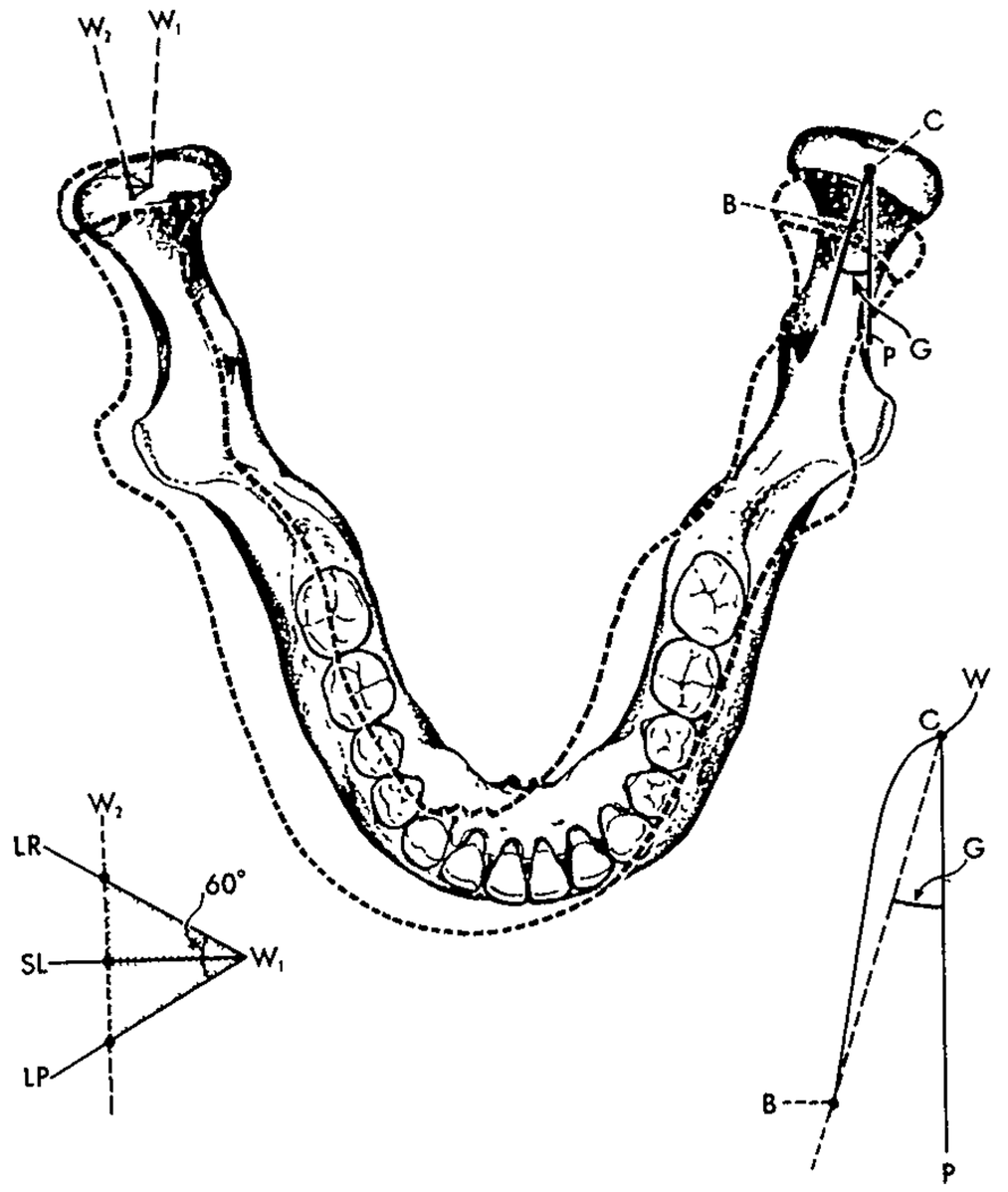

FIGURE 3. Right lateral movement of the mandible viewed in the horizontal plane.

The condyle, during a side shift on the working side, may move straight outward laterally (SL), lateral and protrusively (LP), or lateral and retrusively (LR) from W1 to W2. In effect the condyle may move to any point within the borders of the 60 degree triangle shown in the horizontal plane. On the balancing side the condyle may move from C to point B. The angle G made by the sagittal plane and a line drawn from point C to point B is called the Bennett angle. Bilateral straight forward movement of the condyles (CP) is protrusive.

(From: Ramfjord and Ash 1971)

2.24 Retruded position, intercuspal position and median occlusal position

According to Mathews (1967), a common saying within the dental profession is that centric relation was defined by the prosthodontists, mechanized by their articulators, discussed at great length by the periodontists, redefined in oral rehabilitation, and ignored by the orthodontists. Exaggerated though this description is, orthodontists have been slow in recognizing the importance of a centrically related occlusion (Wood 1977). This has been due to, in great part, the controversy that surrounds the methods of recording the retruded position.

Retruded position and intercuspal position do not coincide in the average human dentition (Ramfjord and Ash 1971). Investigations of normal variations in occlusal relationships in adults and children have shown that the intercuspal position is situated, on the average, 1mm anterior to the retruded contact position (Tallgren, Melsen and Hansen 1979). On the other hand, in subjects with distal occlusion and a large overjet, this relationship can be increased to 3mm or more. Centric stops in retruded position and intercuspal position should be at the same horizontal level to help direct the forces along the long axis of the teeth (Hohl 1978a). This flat area between retruded position and intercuspal position (long centric) is compatible with occlusal, temporomandibular joint and muscle harmony according to Ramfjord and Ash (1971) and Dawson (1974). On the other hand, Behrend (1973) and Jankelson (1979) question the validity of providing 0.5 to 1.0mm of long centric.

Roth (1981a) claims that for years the emphasis in describing centric relation of the mandible has been the rearmost position. This, he says, is unfortunate, because the emphasis should have been placed upon capturing the uppermost or superiormost, position attainable. This is in agreement with the definition of Dawson (1974).

Ismail and Rokni (1980) conducted a study to compare the spatial relationship of the condyles to their fossae in the intercuspal and retruded positions, using right and left temporomandibular joint radiographs on 40 young adults. Their findings substantiate the retruded position as being posterior and superior. They also showed that in intercuspal position, the condyles were centrally located antero-posteriorly in their fossae, with equal anterior and posterior joint spaces. Greater spatial differences existed between the retruded and intercuspal positions on the side which was the orbiting side condyle. They also advocate the use of the long centric position for establishing and reconstructing occlusions.

Weinberg (1979) stresses that the retruded position of each patient should be individually evaluated by comparing the radiographs. Weinberg (1980) differentiates between "functional" and "dysfunctional" retruded position. The retruded position is functional in two situations:
A. When there is no retruded position deflective contact, and the condyles are symmetrically placed in the middle of each fossa.
B. When a retruded position deflective contact is present and the "hit and slide" to the acquired intercuspal position can be correlated with the condylar displacement observed in the temporomandibular joint radiographs.
The retruded position is dysfunctional when:
A. There is harmony between retruded position and intercuspal position, and the condyles are not symmetrically placed in the middle of the fossae.
B. A retruded position deflective contact and the "hit and slide" to the acquired intercuspal position cannot be correlated with the condylar displacement as observed in the temporomandibular joint radiographs.

Radiographic interpretation of condylar position is enhanced by the use of the temporomandibular joint laminagraph or tomograph. Tn this technique special X-Ray equipment is used to make a radiographic "slice" through an anatomical part at a predetermined level to visualize anatomical

structures that are obscured by overlying structures (Bechwith, Monfort and Williams 1980). In lateral temporomandibular joint laminagraphy, the radiographic "slice" is made through the condyle and fossa, between the medial and lateral poles of the condyle.

Kantor, Silverman and Garfinkel (1972) compared the retruded position records obtained by using five techniques. Bilateral manipulation of the mandible produced the smallest area of displacement of the maxillo-mandibular records. Records with chin-point guidance showed relatively less consistency, while the free-closure or swallowing, and Myomonitor techniques produced the least consistency. The most protrusive positions were recorded with the free-closure and Myomonitor techniques. The most retrusive records were produced with the technique of chin-point guidance with an anterior jig.

Williamson, Steinke, Morse and Swift (1980) found that interocclusal records made with the leaf gauge and with the patient biting hard, tend to cause the mandibular condyles to be forced posteriorly and away from the articulating surface of the eminence. Interocclusal records made with the leaf gauge and with the patient biting easy, appear to allow physiologic placement of the mandibular condyles in the glenoid fossae, according to their study.

Weinberg (1979) says that clinical experiments have demonstrated a variation in the duplicability of the retruded position record relative to time, stimulus, and method, which strongly suggests that the posterior condylar position is influenced more by balanced muscle tone than by ligaments. Gelb (1975) supports the idea that retruded position is dynamic and variable. Levy (1975,1976) presents a dynamic or alterable concept of retruded position, and puts forward Begg's work with the dentitions of Stone Age man as an example. Levy says that the mandibles of Begg's specimens had migrated mesially along with the tooth to tooth migration. Mathews (1967) states that the adjustive tolerance of the temporomandibular joint suggests

there is a small but definite range of possible condylar positions which will vary in degree from person to person, all of which could be considered as being representative of retruded position and essentially correct for the individual. Moss (1975) claims that in short time periods the dynamically fluctuant state of the neuromuscular apparatus makes it reasonably certain that intra-individual variation in condylar positions can exist. Over relatively long periods of time, he says, the morphology of all functional surfaces of the temporomandibular joint is capable of significant adaptive alterations. These authors, therefore, dispute the concept of an immutable condylar position, defined as "retruded position", especially in the growing individual.

Occlusal co-ordination can be examined by asking the patient to open his mouth widely, and then snap it shut. In the absence of deflective occlusal contacts, this results in an instantaneous, accurate interdigitation into the median occlusal position (McNamara 1977). In healthy individuals, median occlusal position is assumed to be that position of harmony for the dentition, temporomandibular joint and masticatory musculature from which precise jaw movements commence and automatically terminate (McNamara 1976a). According to Moyers (1973), it is the only occlusal position showing muscle balance. McNamara (1976b) showed that median occlusal position produced the longest inhibition of elevator muscle activity, and he considers it to be the test parameter to evaluate the harmony of neuromuscular integration. The median occlusal position in the infant seems to coincide with the unconscious swallowing position of the mandible and is forward of the most retruded mandibular position (Moyers 1973). During eruption and development, the teeth are guided into occlusion by this congenital reflex, according to Moyers. At this early age, the intercuspal position and the median occlusal position are the same; later in life they are often different. Moyers (1973) and McNamara (1978) believe that all occlusal correction should be aimed at achieving a repeatable median occlusal position by stabilizing the intercuspal

tooth position in harmony with the joint relationship. The median occlusal position contacts cannot be captured on mounted casts, as they approximate functional tooth contacts, but are important during occlusal adjustment procedures (Klineberg 1980b).

2.3 FUNCTIONAL MOVEMENTS OF THE MANDIBLE

Functional movements of the mandible occur in mastication, deglutition and speech. Parafunctional movements include those used in bruxism, lip and cheek biting, and chewing on foreign objects (Behrend 1973).

In reality, mastication and deglutition are one continuous action (Conny 1980). Bates, Stafford and Harrison (1975) provide a comprehensive review of the literature on masticatory function. Muhlemann (1971) presents a review of the literature on occlusal radio telemetry studies. Chewing contacts occur most of all in the intercuspal position, relatively less so in lateral excursions, and least of all in the retruded position. The number and duration of contacts are individual, and are influenced by the material chewed, increasing towards the end of mastication. The occlusal contacts can take the form of point contacts or sagittal or transverse gliding contacts (Muhlemann 1971).

The pattern of movements of the anterior region of the mandible during the masticatory cycle varies considerably between individuals, although any one individual usually has a characteristic pattern (Matthews 1975). Ahlgren (1967) found that, in patients with malocclusion of the teeth, both of the morphologic and functional type, chopping masticatory strokes were common. A large percentage of reversed, contralateral and irregular masticatory strokes were found also. In patients with "normal" occlusion, the masticatory movements were more regular and consistent in form, and with less individual variation. Ahlgren points out, however, that deviations in the form of the masticatory movements do not necessarily have to be indicative of inferior masticatory function.

Deglutition is a complex neuromuscular activity (Conny 1980). According to Lavelle (1975), the infantile swallow pattern changes to the adult swallow pattern during a transitional period which is conditioned by the neuromuscular maturation,

change in head posture, and the gravitational effect of the mandible. Usually, by 18 months of age, the following mature swallow characteristics are to be observed:

A. The teeth are together
B. The mandible is stabilized by contraction of the mandibular elevators
C. The tongue tip is held against the palate above and behind the incisors
D. There are minimal contractions of the lips.

Lavelle (1975) divides tha mature deglutition cycle into:

A. Preparatory phase
B. Oral phase
C. Pharyngeal phase
D. Oesophageal phase

Lavelle says that it is during the swallow preparatory phase that "considerable pressure" is exerted between the teeth in the molar region, as the lip is elevated to position the bolus. He says that this phase is initiated voluntarily, with the cerebral cortex playing the dominant role. The glossopharyngeal nerve (IX) is primarily responsible for afferent information in the initiation of swallowing by the mucous menbrane, and the pharyngeal branch of the vagus plays but a minor role.

Moyers claims that unconscious swallowing occurs forward of the retruded contact position, perhaps with what was earlier the median occlusal position in the young child (Moyers 1973). He says that since volitional swallowing may be made in any position, care must be taken in the interpretation of research papers on swallowing and mandibular position. All investigators do not differentiate between unconscious, volitional and command swallows, nor do they always mention the amount and substance being swallowed.

Tooth contacts in swallowing are of longer duration than in chewing, but there is wide variation in frequency and duration from one subject to another (Ramfjord and Ash 1971). It appears that retruded position is important as a functional border position of the mandible in swallowing

(Ramfjord and Ash 1971). They say that the mandible normally slides forward from the initial contact in retruded position and is seated in intercuspal position during swallowing. The applied forces appear to be related to the individual muscle tone, which again is related to psychic tension (fusimotor activity) and occlusal interferences or prematurities (Ramfjord and Ash 1971).

Thus, as indicated by the studies on morphology and mastication and swallowing, maximal intercuspation in a maxillo-mandibular relation within a small range anterior to the retruded contact position, must be considered physiologically normal (Beyron 1969).

CHAPTER 3

Static Occlusion

and

Functional Occlusion

3.1 CLASSIFICATION OF OCCLUSAL CONCEPTS

The subject of occlusion has remained controversial because various concepts have been developed by different clinicians striving toward the same goal (Gelb 1975). Controversy arises in relation to the degree of correlation of the occlusion to mandibular border movements deemed necessary, and to the particular occlusal scheme to be employed, and also the type of instrumentation to be utilized (Roth 1973). The orthodontist affects all the components of the masticatory system during treatment and therefore requires an understanding of occlusion that goes beyond a solely anatomical classification of malocclusion as a basis for orthodontics (Timm, Herremanns and Ash 1976).

Static occlusion refers to the form, alignment, and articulation of the teeth within and between the arches, and the relationship of the teeth to their supporting structure (Gazit and Lieberman 1973). Static occlusion may be classed as normal or maloccluded. Dynamic occlusion refers to the function of the stomatognathic system as a whole, comprising teeth, supporting structures, temporomandibular joints, neuromuscular and nutritive systems. Dynamic occlusion may be either physiological or pathological. The ultimate in occlusion exists when the anatomical and physiological occlusions have been produced to the highest degree (Thompson 1956).

Ricketts (1979) suggests four different occlusal definitions: A. Normal occlusion- an untreated natural occlusion that is within an expected normal range of variation in all of the measurements thought to be critical in evaluating occlusion. Ramfjord and Ash (1971) say that normal occlusion should imply more than a range of acceptable values; it should indicate physiological adaptability and the absence of recognizable pathological manifestations. Such a concept of normal occlusion emphasizes the functional aspect of occlusion and the capability of the masticatory system to adapt to, or compensate for, some deviations within the range of tolerance of the system.

B. Ideal occlusion- represents an occlusion in which there is perfect size and fit of the individual teeth, and the teeth are in ideal arch form, balance, and harmony; an occlusion in which every incline and stop is perfect, and every tooth is in ideal location within its arch, and functions perfectly with its opponent teeth in the opposite arch (Ricketts 1979). Ramfjord and Ash (1971) say that the concept of ideal occlusion is a state in which there is no (or minimal) neuromuscular adaptation needed because there are no occlusal interferences present. Ideal occlusion refers both to an aesthetic and physiological ideal. Ideal occlusion is a man-made definition, an ideal, a description of a small part of biological normalcy, that part that is both biologically and socially normal (Hixon 1972).

C. Reconstructed occlusion- represents those occlusions that have been restored, where the ability to critically record jaw movement is essential (Ricketts 1979). The occlusion is designed to accommodate to the pathways of function recorded for the individual case, and the teeth can be "constructed" to function properly in all movements in the specific case.

D. Orthodontic finishing occlusion- represents the occlusion that is desired at the time of band or active appliance removal. This may incorporate a concept of overcorrection in order to compensate for the original malocclusion and the abnormal function that was originally present. The prevailing idea is that natural forces of occlusion combine with those of physiology and growth to settle functionally into the best position for each individual's characteristics.

Hixon (1972) believed one of the problems we have in orthodontics today is the definition of normal:

A. Statistical or average-

a. Most frequent, usual, popular, the mode

b. Typical - a statistical approximation is sometimes considered to be the mean with normal variation defined by $\pm$ 2 standard deviations

B. Functional- Does it work?

Not harmful, not painful, and non-pathologic

C. Idealistic- The way it ought to be

a. Orthodontic or anatomic (Angle's "Old Glory")

b. Gnathologic

-cuspid protection is normal

-group function is normal

-terminal hinge is normal

-abrasion is normal

c. Anthropologic

-abrasion is normal for continuous self-equilibration.

Beyron(1969) believes there is no normative form, and occlusal disharmony cannot be described in terms of deviation from an idealized type of occlusion. Most authors agree, however, that for the purpose of treatment it is necessary to recognize certain characteristics of an optimum occlusion, so that the orthodontist has a basis or goal upon which to treat.

3.2 ATTRITIONAL OCCLUSION

Man did not always demonstrate marked occlusal-cusped anatomy (Fishman 1976). Civilized man exhibits relatively little dental attrition, but more primitive societies possessed teeth with marked degrees of wear. The role of attrition is one of the most controversial and challenging aspects of occlusion (Seward 1976).

Begg and Kesling (1977) discard the concept of textbook normal occlusion as a fallacy, and have adopted Stone Age man's attritional occlusion as the basis of orthodontics, because they believe that it is the anatomically and functionally correct occlusion. In this occlusion the positional relationships of the individual teeth to each other in the same dental arch, the occlusal relationships of the teeth of one dental arch to those of the opposite dental arch, and the relationships of the teeth to the jaws, change continually throughout life in two directions - horizontal (mesial migration), and vertical (continued eruption). The plane of attrition of the upper and lower incisors becomes horizontal, and an edge-to-edge occlusal relationship of Stone Age man's upper and lower permanent incisors is

established. Stone Age man's curve of Spee is not nearly so curved as in textbook normal occlusion. It is usually almost a flat plane mesiodistally. The elimination of the incisor overbite freely permits lower permanent incisors to tip labially, and upper permanent incisors to assume more vertically upright axial inclinations. The molar, premolars and canines eventually assume typical Angle Class lll occlusal relations.

Thus form and function teamed together to produce a dental apparatus that was well aligned and well balanced, with harmony between the three major tissue systems- tooth, bone, and muscle (Graber 1969). Sirna (1968) presented a number of differences between the early European skulls he studied (dated from the early sixteenth century to the early nineteenth century) and the aboriginal material presented by Begg:

A. Attrition not as severe
B. The flat posterior occlusal plane as an intermediate stage toward the development of the anti-Monson curve was not observed
C. No occlusions of the X-type were observed
D. A decrease in denuded dentine
E. A well established curve of Spee

He believed this pattern of attrition was due to the dominance of lateral strokes or eccentric movements in the well-exercised dentition. He looks at the phenomenon of decreased attrition of the contemporary dental crown as one of the more obvious anthropological and physiological manifestations of human adaptation. Seward (1976), on the other hand, considers tooth attrition pathological, and that a relationship exists between temporomandibular joint disturbances and dental attrition in the skulls of adult Australian aboriginals. Levy (1975) attributes these changes in the temporomandibular joint to its adaptability, and considers this process to be not necessarily pathological.

With diet changes and less interproximal and occlusal wear, there has been an alteration within the tooth system itself. Part of this alteration results from the different functional

demands being made on the tooth system by modern refined foods; part is a homeostatic or adaptive response to the basal bone modifications of successive generations, as elucidated by the anthropologists (Graber 1969). It is relatively clear that man is developing a greater amount of overjet in his dentition and a significantly deeper overbite. Malocclusion associated with inadequency of arch length to accommodate full dentitions is common (Fishman 1976). However, Fishman says that Begg's contention that normal occlusion is the severe attrition type of dentition is a point that bears little relevance with present-day man. Begg and Kesling (1977) admit that, in civilized man, anatomically correct occlusion is practically nonexistent, because the basic factors that make this occlusion possible are absent. Modern day man does not, and in all probability will not, exhibit severe attrition (Fishman 1976).

Certainly Begg's ideas on attritional occlusion have helped in explaining the aetiology of malocclusion, in planning and treating these malocclusions, and in the stability of the end result. Also, functionally his concepts support occlusal equilibration and reproximation. However, at the end of treatment we are still left with an unworn, non-attritional occlusion, which cannot be finished or held in attritional occlusal position, and, as such, we have to apply the concepts of textbook normal occlusion, together with attritional occlusion, to obtain a stable, aesthetic, and functional end-result. Because of this we have to accept a man-made compromise for the well-being of modern man's own dentition and masticatory apparatus.

3.3 NON-ATTRITIONAL OCCLUSION

It seems evident that orthodontics, orthodontists, and patients all would benefit if treatment goals could be objectified (Andrews 1979). As a step in that direction, Andrews (1972) developed six significant characteristics observed in a study of 120 casts of nonorthodontic patients with "normal" occlusion.

3.31 Key I - Molar relationship

A. The distal surface of the distobuccal cusp of the upper first permanent molar made contact, and occluded with, the mesial surface of the mesiobuccal cusp of the lower second molar.
B. The mesiobuccal cusp of the upper first permanent molar fell within the groove between the mesial and middle cusps of the lower first permanent molar.
C. The mesiolingual cusp of the upper first molar seated in the central fossa of the lower first molar.
D. The canines and premolars enjoyed a cusp-embrasure relationship buccally, and a cusp-fossa relationship lingually.

3.32 Key II - Crown angulation (Figure 4)

The gingival portion of the long axis of each crown is distal to the occlusal portion of that axis. Figure 5 shows the average angulations of the upper teeth found in the non-orthodontic models. It appears that nature intends the upper teeth to occupy more room, via angulation, than the lower teeth. The degree of angulation of incisors determines the amount of mesiodistal space they occupy and, therefore, has a considerable effect on posterior occlusion as well as anterior aesthetics.

3.33 Key III - Crown inclination (Figure 6)

In upper incisors the gingival portion of the crown's labial surface is lingual to the incisal portion. In all other crowns, including lower incisors, the gingival portion of the labial or buccal surface is labial or buccal to the incisal or buccal portion (Figures 7 and 8). In the upper arch the lingual crown inclination of the buccal surfaces is slightly more pronounced in the molars than it is in the canines and premolars (Figure 9). In the lower canines, premolars, and molars, lingual crown inclination progressively increases (figure 10).

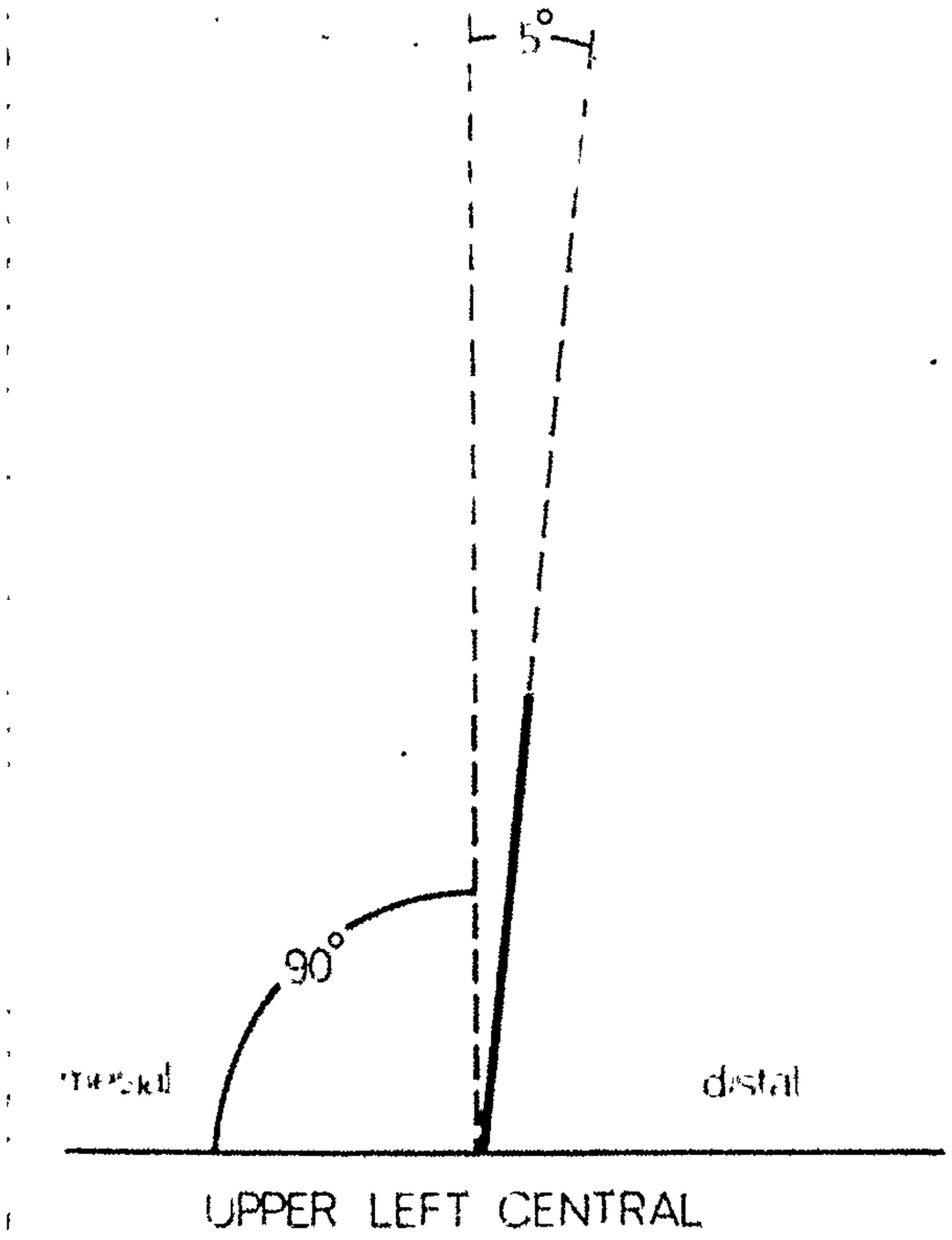

FIGURE 4. Crown angulation (mesiodistal tip).

Measured as the angle between the LACC (long axis of the clinical crown) and a line perpendicular to the occlusal plane.

(From: Andrews 1976)

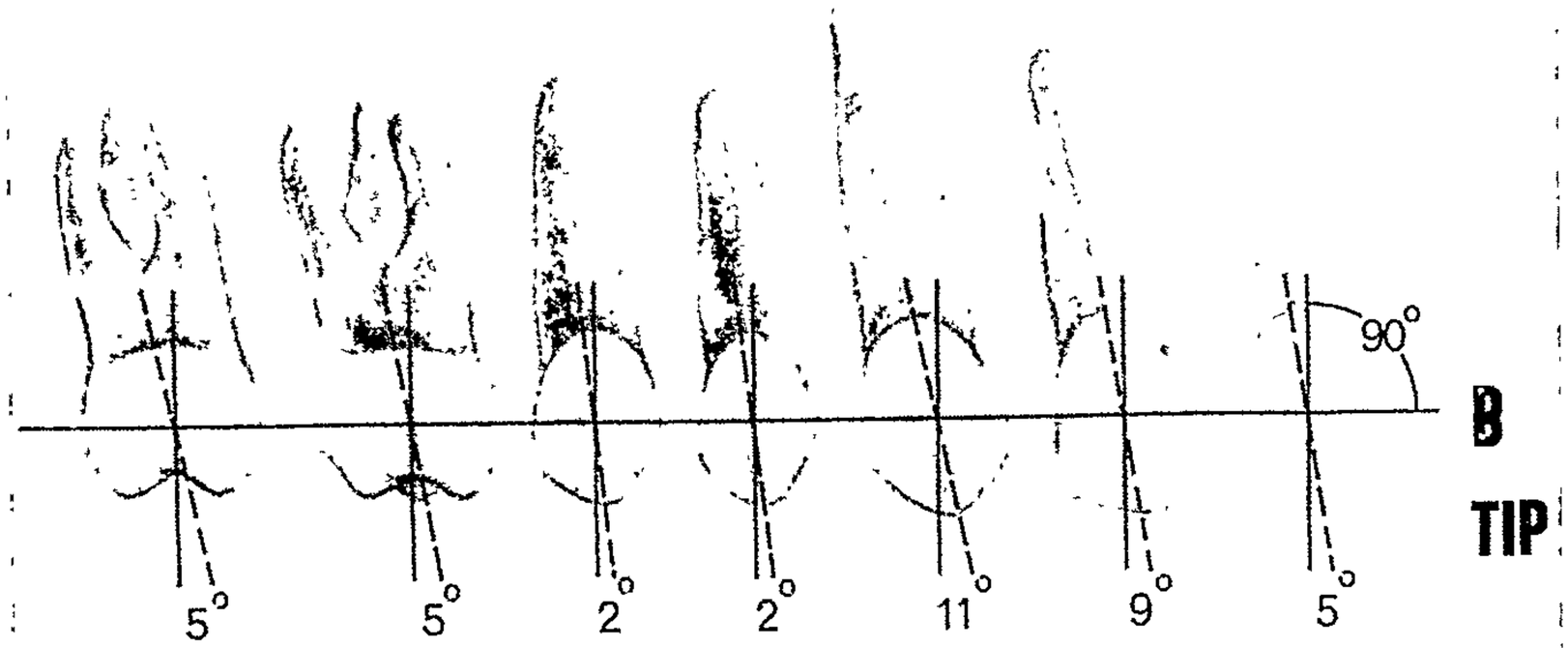

FIGURE 5. Average angulations of upper teeth.

(From: Andrews 1976)

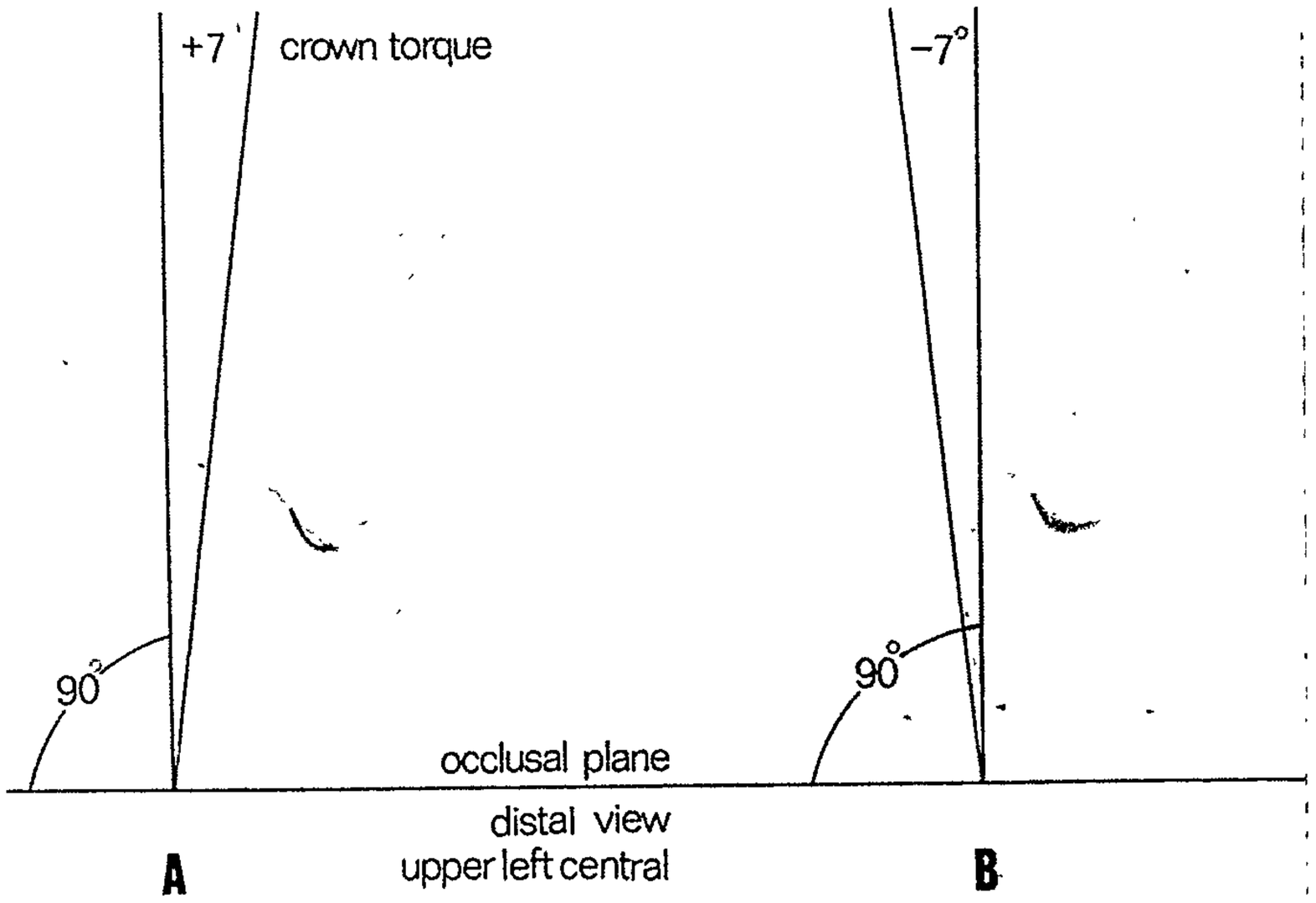

FIGURE 6. Crown inclination.

Measured as the angle between a line 90 degrees to the occlusal plane and a line tangent to the middle of the LACC (long axis of the clinical crown).

(From: Andrews 1976)

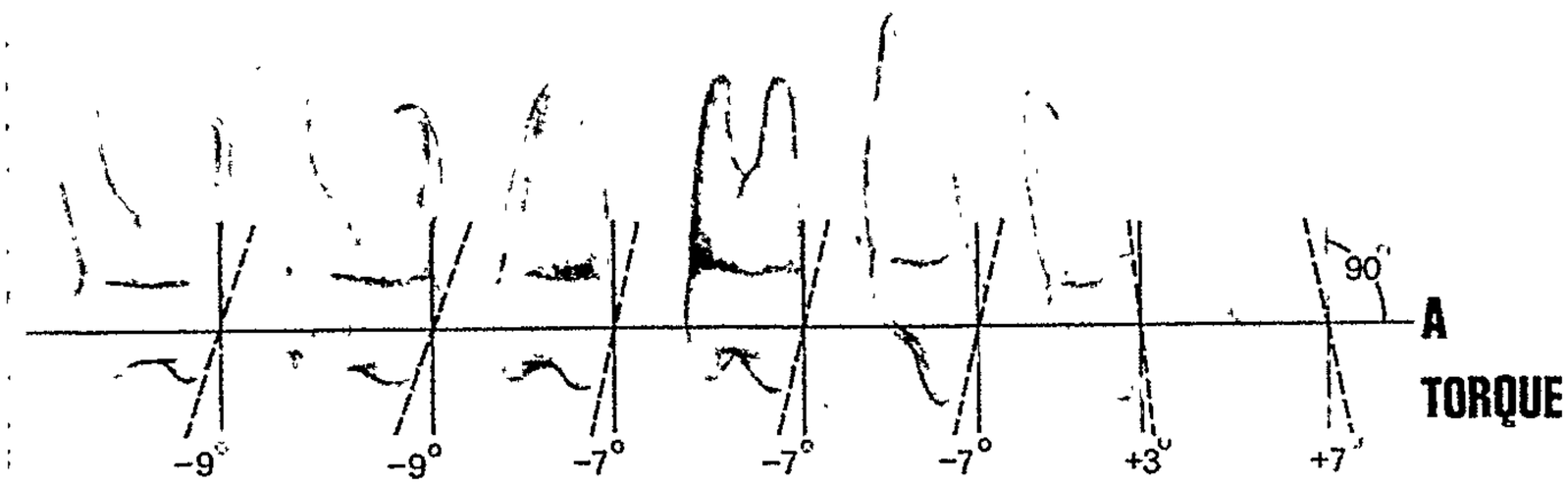

FIGURE 7. Average inclinations of upper teeth.

(From: Andrews 1976)

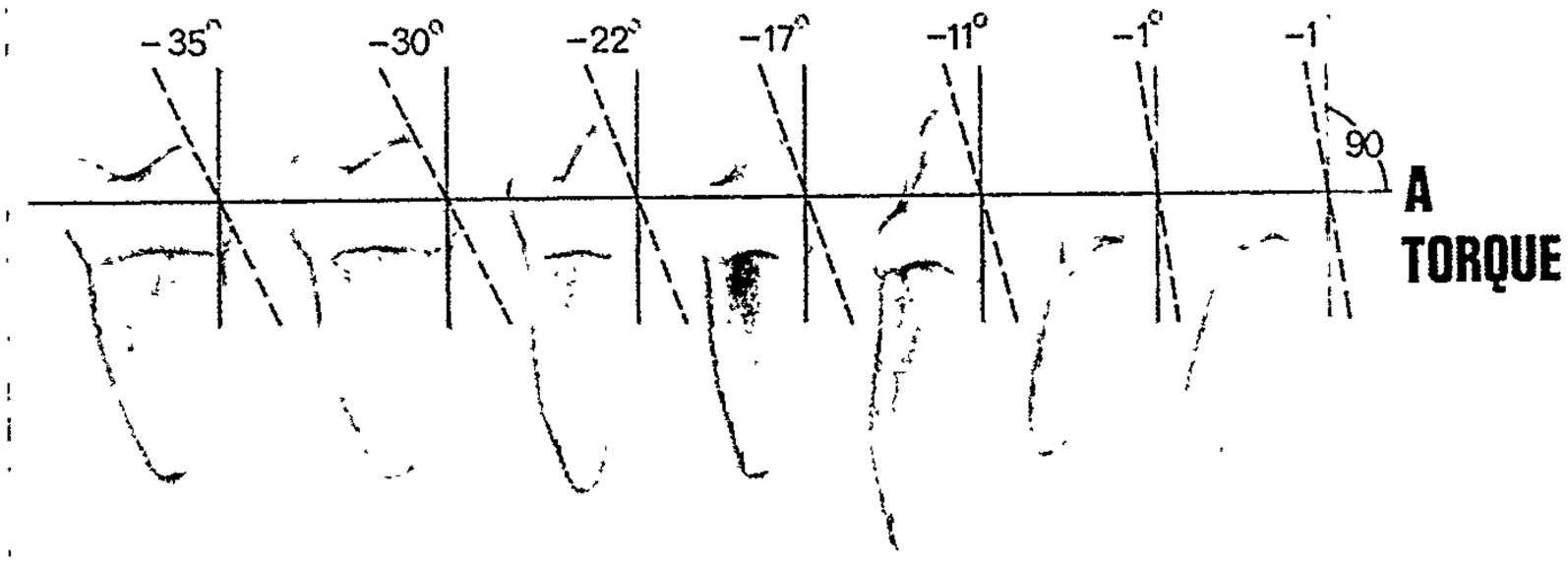

FIGURE 8. Average inclinations of lower teeth.

(From: Andrews 1976)

FIGURE 9. Inclination of the upper posterior teeth is similar from canines through premolars, and is slightly more pronounced in the molars.

(From: Andrews 1976)

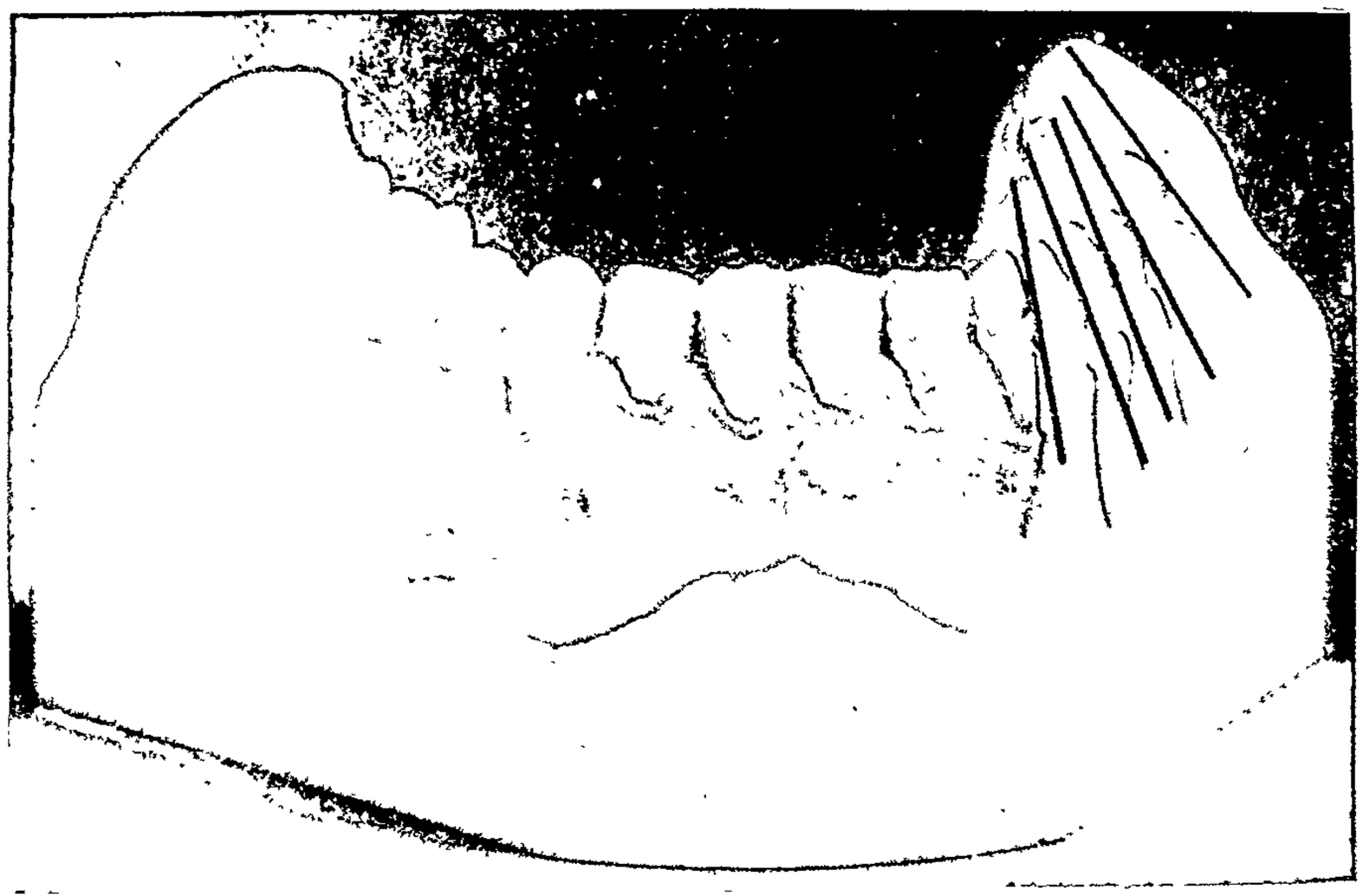

FIGURE 10. Inclination of lower posterior teeth progressively increases from canines through molars.

(From: Andrews 1976)

3.34 Key IV - Rotations

Teeth should be free of undesirable rotations. A rotated molar or premolar occupies more space than it normally does, while a rotated incisor may occupy less space. Both of these types of rotations affect the position and occlusion of adjacent and other teeth (Figure II).

3.35 Key V - Tight contacts

The contact points should be tight, although persons with genuine tooth-size discrepancies pose special problems.

3.36 Key VI - Curve of Spee (Figure 12)

The curve of Spee should have no more than a slight arc. The deepest curve of Spee in the nonorthodontic "normal" models was 1.5mm (from incisors to second molars).

3.4 NON-ATTRITIONAL FUNCTIONAL OCCLUSION

3.41 Criteria for optimal functional occlusion

McNamara (1977) states that a biologically optimal occlusion ensures a stable neuromuscular pattern of the masticatory system that is self-perpetuating. Minimal stress occlusion permits the entire range of the stomatognathic system to function harmoniously, with no excessive demands placed on the joints, the ligaments, the neuromuscular system, or the teeth (Dawson 1974).

There are five criteria that should be fulfilled if an occlusion is to function with optimal stability and maintainability (Dawson 1974):

A. Stable stops on all teeth when the condyles are in their most superior, posterior position.
B. An anterior guidance that is in harmony with the border movements of the envelope of function.

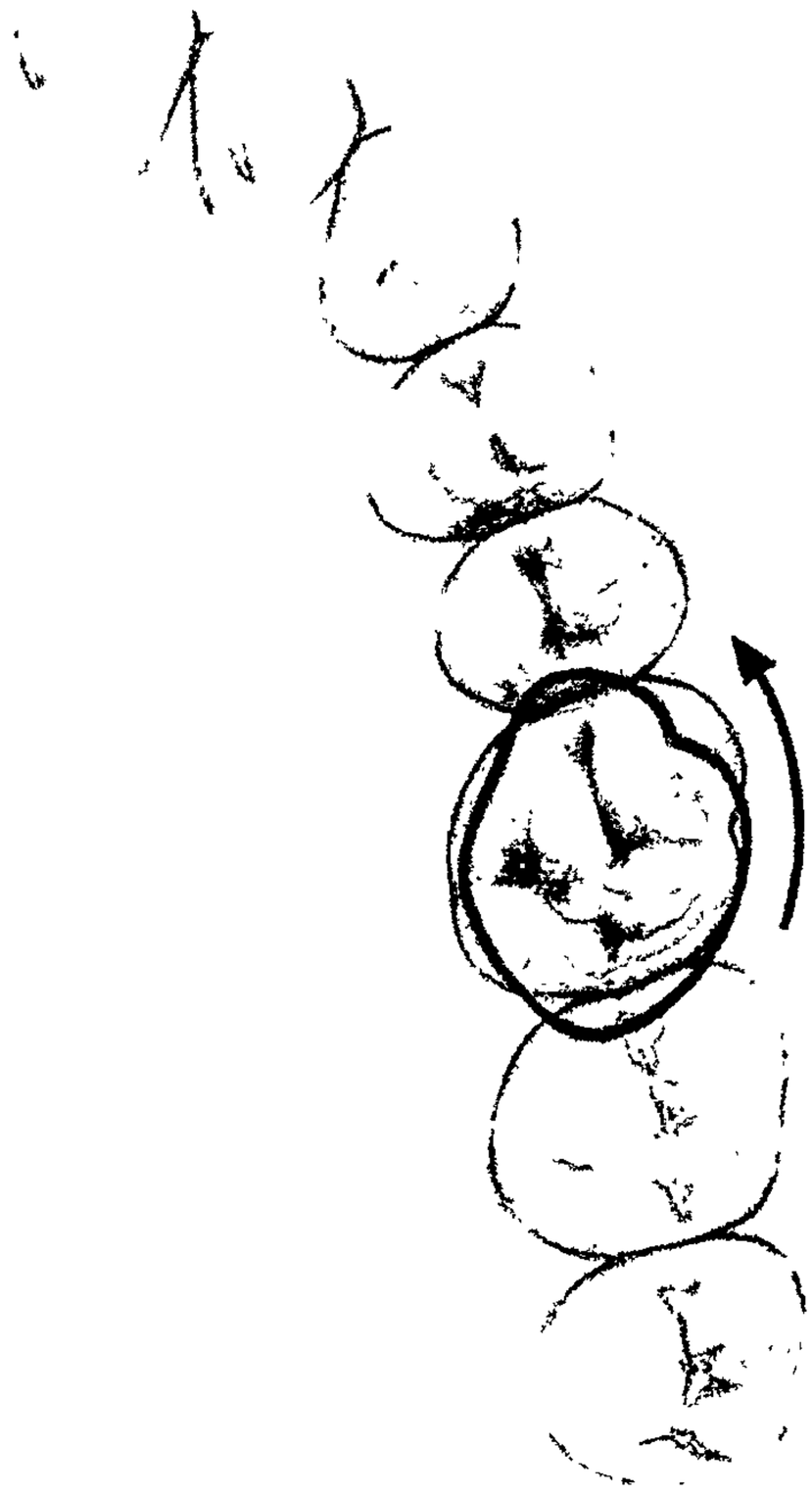

FIGURE 11. A rotated molar occupies more mesiodistal space.

(From: Andrews 1976)

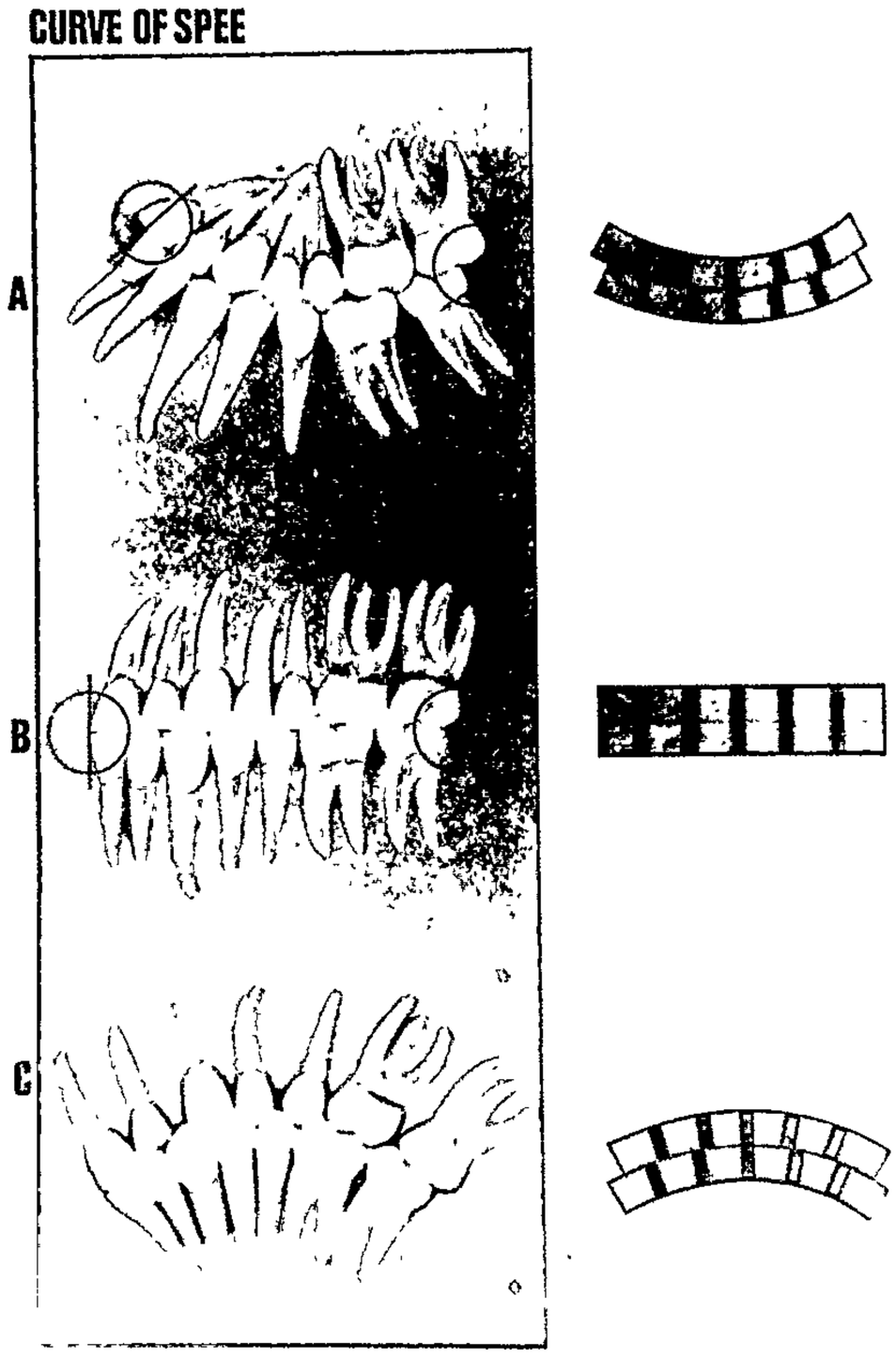

FIGURE 12. Curve of Spee.

A. A deep curve of Spee results in a more confined area for the upper teeth.

B. A flat curve of Spee is most receptive to "normal" occlusion.

C. A reverse curve of Spee results in excessive room for the teeth.

(From: Andrews 1976)

C. Disclusion of all posterior teeth on the balancing side (the side of the orbiting condyle).
D. Disclusion of all posterior teeth in protrusive movements.
E. Noninterference of all posterior teeth on the working side, with either the lateral anterior guidance, or the border movements of the condyles.

Behrend (1973), Roth (1976) and Barnett (1978) provide similar criteria for an optimal functional occlusion.

3.42 The importance of anterior guidance

McHorris (1979) says that nothing pleases occlusion-conscious dentists more than to see orthodontically treated teeth with good centric closures, and effortless disclusions, provided by proper horizontal and vertical overlaps of aesthetically pleasing anterior teeth. In his opinion, anterior teeth are the key to preserving good occlusions. The posterior teeth are designed and capable of withstanding vertical stress (Lucia 1979). They stop the closure and, as long as the forces are in the vertical axis of the teeth, no damage can be done.

In spite of how good the upper front teeth may look, their chance of staying healthy and keeping the back teeth healthy, depends on their lingual contours, specifically the contact of the lower anterior teeth against the upper anterior teeth in centric, long centric, straight protrusive, and lateral excursions (Dawson 1974). This dynamic relationship of the lower anterior teeth against the upper anterior teeth through all ranges of function is called anterior guidance. Schuyler (1963) defined anterior guidance as the influence on mandibular movements provided by the contacting surfaces of the maxillary and mandibular anterior teeth. Dawson (1974) prefers anterior group function, whenever possible, for discluding the posterior teeth in lateral and protrusive excursions. If this is not possible, canine-protected occlusion is used, which is part of mutually protected occlusion. This refers to an occlusal arrangement in which the posterior teeth contact in centric relation only, the incisors are the only teeth contacting

in protrusion, and the canines are the only teeth contacting in lateral excursions. Most people with natural teeth can be categorized as belonging to the group function type of functional occlusion pattern if they exhibit occlusal contacts on several teeth in lateral eccentric mandibular excursions, or to the canine-protected type if no contact is made on the posterior teeth in lateral mandibular excursions because of contact of their canine teeth (O'Leary, Shanley and Drake 1972).

The mutually protective type of occlusal scheme offers the following attributes (Roth 1976):

A. Good stress distribution to the periodontium
B. No need for neuromuscular avoidance movements
C. Discourages grinding, bruxing and clenching
D. Discourages trauma to the temporomandibular joints
E. Discourages neuromuscular dysfunction, muscle contracture, muscle spasm or muscle splinting
F. Promotes masticatory efficiency
G. Promotes proper tooth contact and correct swallowing
H. Promotes proper articulation during speech
I. Is comfortable.

The predominant prerequisite for use of the canine-protected occlusion is the capacity of the canine to withstand the entire lateral stress load without any help from other teeth (Dawson 1974). The canine actually assumes the role more as a guidance that actuates vertical function, rather than as a resistor to lateral stress. The canines have extremely good crown-root ratios, and their long-fluted roots are in some of the densest bone of the alveolar process. Furthermore, their position in the arch, far from the fulcrum, makes it more difficult to over-stress them.

Wasson (1979) says that the class III lever principle is employed with anterior disclusion. If more teeth than the mandibular canine on the working side are allowed to contact in lateral excursions, uneven wear is likely to occur because each tooth is a different distance from the rotating condyle and, therefore, moves on a different arc. Also, contact of

teeth posterior to the lower canine will be closer to the muscle or power source and will, therefore, receive more leverage or pressure. Dickson (1980) analysed the mechanics of canine disclusion. Manly, Pfaffman, Lathrop and Keyser (1952) found the threshold for axial forces applied to the canines to be higher than that for the incisors. In other words, the canine was not the most sensitive tooth. On the other hand, Bonaguro, Dusza and Bowman (1969) found the maxillary canine to have the highest discriminatory ability of all human teeth at forces over 200g.

The anterior guidance cannot do its job in the following situations (Dawson 1974):

A. Class II malocclusions with extreme overjet
B. Class III malocclusions when all lower anterior teeth are outside of the upper anterior teeth
C. Some end-to-end bites
D. Anterior open-bites

In mandibular protrusion, the condylar head follows closely the anatomical form of the articular eminence (Corbutt, De Vincenzo, Huffer and Shryock 1971). The anterior discluding path is significantly steeper than the eminence, and the slope of the eminence has less influence upon the slope of posterior cusp paths than has the anterior discluding path (Huffer, De Vincenzo, Corbutt and Shryock 1972). Ingervall (1974) noted certain associations between facial pattern and condyle-fossa relation. He found a deep fossa and a steeper inclination of the eminence in subjects possessing a rectangular, brachyfacial form of face, and a smaller tubercle height and lesser inclination of the condylar path in subjects with high anterior face height, dolichofacial form of face. Perry (1975) suggests establishing a canine-guided occlusion for the dolichofacial type patient, and a group function occlusion for the brachyfacial type patient.

Williamson (1976) presents the characteristics of bilateral balanced occlusion (used in denture construction), group function occlusion, and mutually protective occlusion. Timm, Herremanns and Ash (1976) and Alexander (1963) say that

there is no scientific evidence that group function on the working side is any less desirable, or unhealthy, than canine-guided occlusion. Hohl (1978a) suggests that it may be an advantage to provide group function for older patients, to distribute lateral forces over a greater number of teeth. Group function may also be preferable where a canine has been surgically exposed and brought down into occlusion, and has reduced bone support. The canine teeth are subject to the same destructive effects of periodontal disease as other teeth, when the aetiologic factors capable of producing the disease are present (Alexander 1963). O'Leary, Shanley and Drake (1972) found that the mean mobility of maxillary canines was greater in canine-protected lateral movements than those with group function. They say that canine protection may be physiologic for many people, but the practice of altering occlusal relations to establish canine protection as a prophylactic measure, is open to question. Goldstein (1979) evaluated different occlusal concepts and their relationship to the periodontal index. He found that the teeth of mouths having canine-protected occlusions had significantly lower mean periodontal disease index scores than the teeth in mouths having progressive disclusion or group function.

Beyron (1964) found that Australian aborigines who had excellent, well-functioning dentitions, also had group function on the working side, and no contact on the non-working side. Weinberg (1961) examined 60 patients, selected at random, for signs of tooth-to-tooth contact in eccentric positions of the jaws. Of the 60 patients used in this study, 59 (98.3%) showed some signs of tooth to tooth contact in eccentric positions, and 84% of the total teeth examined exhibited eccentric wear facets. Weinberg found multiple tooth contacts on the functional side to be the rule, while canine protection occurred in only 19% of the subjects. Scaife and Holt (1969) examined 1,200 patients aged 17 to 25 years, and found bilaterally-protected occlusion in 57% of the subjects, 16.4% with a unilateral canine protection and 26.6% without canine-protected

occlusion. The incidence of natural canine protection in lateral movements was broken down into relative occurrence in relation to Angle's class of occlusion. Class I subjects exhibited a 57% incidence of bilateral canine contact and an additional 16% unilateral contact. Class II subjects had a 67% occurrence of bilateral protection and 17% unilateral protection. Class III subjects had only 13% bilateral protection and 20% unilateral protection. The percentage of patients with observable facets on teeth increased in indirect proportion to the degree of canine protection. Ingervall (1972) studied 50 children (mean age 11 years) and 50 adults (mean age 23 years), all with morphologically "good" occlusion and without symptoms of functional disturbances of the masticatory system. The majority of the subjects had multiple tooth contacts on at least one of the working sides. Canine protection was found unilaterally in only 18% of adults, and bilaterally in only 2% of adults. The findings of Ingervall (1972) were therefore in agreement with those of Beyron (1964) and Weinberg (1961), but not in agreement with the high percentage of canine-protected occlusion found by Scaife and Holt (1969).

3.43 Harmony with condylar guidance

Wasson (1979) says that the amount of overlap of the canines and incisors must be in harmony with the condylar movement, as well as with the other factors, such as the cusp height of the posterior teeth, and the angle of the the occlusal plane. The angle of the anterior guidance should be the same, or slightly greater than the angle of the condylar guidance. This will allow the mandible to move freely, because the teeth are in harmony with condylar guidance. If the anterior guidance path is much steeper than the condylar guidance, then a restriction of jaw movement occurs and the muscles will be confined. The effect produced would be the same as a posterior interference because a neuromuscular avoidance pattern would have to be established to guide the jaw against the steep angle of the anterior guidance. An anterior interference is just as bad as a posterior interference (Roth 1981c).

This is particularly true if canine overlap is excessive, and if there is a great deal of immediate side shift resulting in a lateral thrust of the mandible as soon as eccentric movement is begun (Wasson 1979) The aim is to provide the most gentle angle of anterior guidance that will safely disclude the posterior teeth. However, if the disclusion is not steep enough, posterior interferences will occur, resulting in the potentially damaging fulcrums. The posterior occlusion should be organized in harmony with mandibular movements, so that very little lift is necessary to keep the posterior teeth from colliding (Roth 1981c).

Williamson (1981) says that, from his electromyographic studies, he has observed that, with posterior tooth contact in any eccentric movement of the mandible, the masseter and temporalis are very active, placing forces on the posterior teeth which are at angles to the long axis of the teeth. If there are no posterior tooth contacts in eccentric mandibular movements, the temporalis and the masseter are electrically quiet on the balancing side, while the temporalis (a positioning muscle with relatively light force) is the only one active on the working side. Therefore, he says, with proper anterior guidance, the front teeth accept a relatively small load from the musculature when the back teeth are not contacting.

3.44 Criteria for ideal tooth positioning

Roth (1981c) gives his criteria for "ideal" tooth positioning:

A. Lower incisors at the cephalometric goal (+1mm to A-Po); for facial aesthetics, for planning anchorage control, and for selecting the most appropriate mechanics to reach this goal.
B. Tips of the upper incisors 2-2.5mm below the lip embrasure of the upper and lower lips, when the lips are closed with no lip strain.
C. No more than 1mm of attached gingiva showing upon a full smile.
D. Approximately a 2.5mm overjet-overbite relationship at the

tip of the upper incisor in its relationship to the lower incisor. (The lower incisor would have .0005" clearance with the lingual surface of the upper incisor, but the articulating paper mark would occur 2.5mm gingival to the incisal edge of the upper incisors.)

E. A level or nearly level occlusal plane at the end of appliance therapy that would return to a 1 to 1.5mm curve, at its deepest point, after appliance removal and settling of the occlusion.

F. A curve of Wilson that would allow seating of centric cusps, but clearance upon excursions.

G. As much divergence as possible of the occlusal plane from the angle of the eminence for excursive clearance.

H. Lower incisors aligned contact point-to-contact point with the roots in the same plane, when observed from the occlusal, and a mesioaxial angulation of 2 degrees.

I. Lower canine crowns angulated mesially 5 degrees, with the incisal tip 1mm higher than the incisal edge of the lateral incisors. The lower canines should have a slightly exaggerated mesial rotation on extraction cases.

J. The lower premolars should be uprighted 1 degree from their normal mesial angulation and should have a slight distal rotation (more so on an extraction case). The contact point should be adjacent to the contact point on the lower canine distal surface.

K. The lower molars should be uprighted 1 degree from their normal 2-degree mesial angulation, and should have a slight distal rotation.

L. The lower buccal segment should have progressive inclinations close to Andrews' measurements for establishing the curve of Wilson, and there should be no rotations or spaces.

M. The upper six-year molars should have sufficient distal rotation, mesioaxial angulation, and crown inclination, so as to fit with the lower six-year molars, as described by Andrews. The same would follow for the upper second molars. The crown inclination requirement would be what is required for the seating of the centric cusps, approximately 14 degrees inclination and 0 degrees mesial angulation.

N. The upper canine must have its contact points adjacent

to the contact points of the upper premolars and lateral incisor, to establish proper length for canine guidance. It should have 11 to 13 degrees of mesial crown angulation and mesial rotation of 4 degrees, on an extraction case.

O. The upper lateral and central incisors should be almost equal in incisal edge length, with no more than 0.5mm height differential. They should have 9 degrees and 5 degrees mesioaxial angulation respectively, and there should be sufficient crown inclination so that the six upper anterior teeth can contact the six lower anterior teeth and the upper canines can lift off the lower premolars in a protrusive excursion.

P. There should be no rotations (other than those for overcorrection) or spaces in the upper arch, and the buccal segments from the canines distally should have 14 degrees nonprogressive crown inclinations.

Q. The arch form should be a modified catenary curve consisting of five separate radii - one for the front of the arch form, one for each canine-premolar area and one for each buccal segment from the first premolar distally. The widest point of the maxillary arch would be at the mesiobuccal cusps of the first molars.

CHAPTER 4

Occlusal Contacts and Interferences

4.1 IDEAL INTEROCCLUSAL CONTACTS

Roth (1981c) says that all centric stops should hit equally and simultaneously, and the stress of closure should be directed, as nearly as possible, down the long axis of the posterior teeth. There should be no actual contact of the anterior teeth in centric closure (0.0005" clearance).

The occluding posterior cusps, called stamp cusps, are the maxillary lingual and mandibular buccal cusps (Wasson 1979). The maxillary buccal and mandibular cusps that do not occlude in a fossa are called shearing cusps (Figure 13). In a cusp-fossa occlusion, the upper stamp cusps fit into all but the mesial fossae of the lower teeth, while the lower stamp cusps fit into all the upper fossae except the distal ones of the premolars, giving a three-point contact around each cusp. Most natural teeth fit together best in a cusp-embrasure relationship in which the buccal cusps of the premolars occlude in the embrasure. This represents the classic Angle Class I occlusion, whereas the cusp-fossa occlusion appears to have a slight disto-occlusion. The best posterior tooth arrangement for any individual may vary from the classic Angle Class I to the cusp-fossa relationship, according to the individual anterior tooth-size ratio, and their angulation, inclination and overbite.

In orthodontic treatment, it is important to be aware of the best location for the interocclusal contacts, and to strive to achieve as many as possible (Figure 14). The number of contacts achieved, however, may not be as important as their location. There should be at least one contact on each tooth to offset movement in each direction. Contacts on the mesial slopes of the lower cusps are called closure stoppers, because they stop the mandibular arc of closure against closure stoppers on the distal slopes of the upper cusps. To offset movement in the opposite direction, each tooth should have an equalizer contact. These are located on the distal slopes of the lower cusps and mesial slopes of the upper cusps (Figure 15).

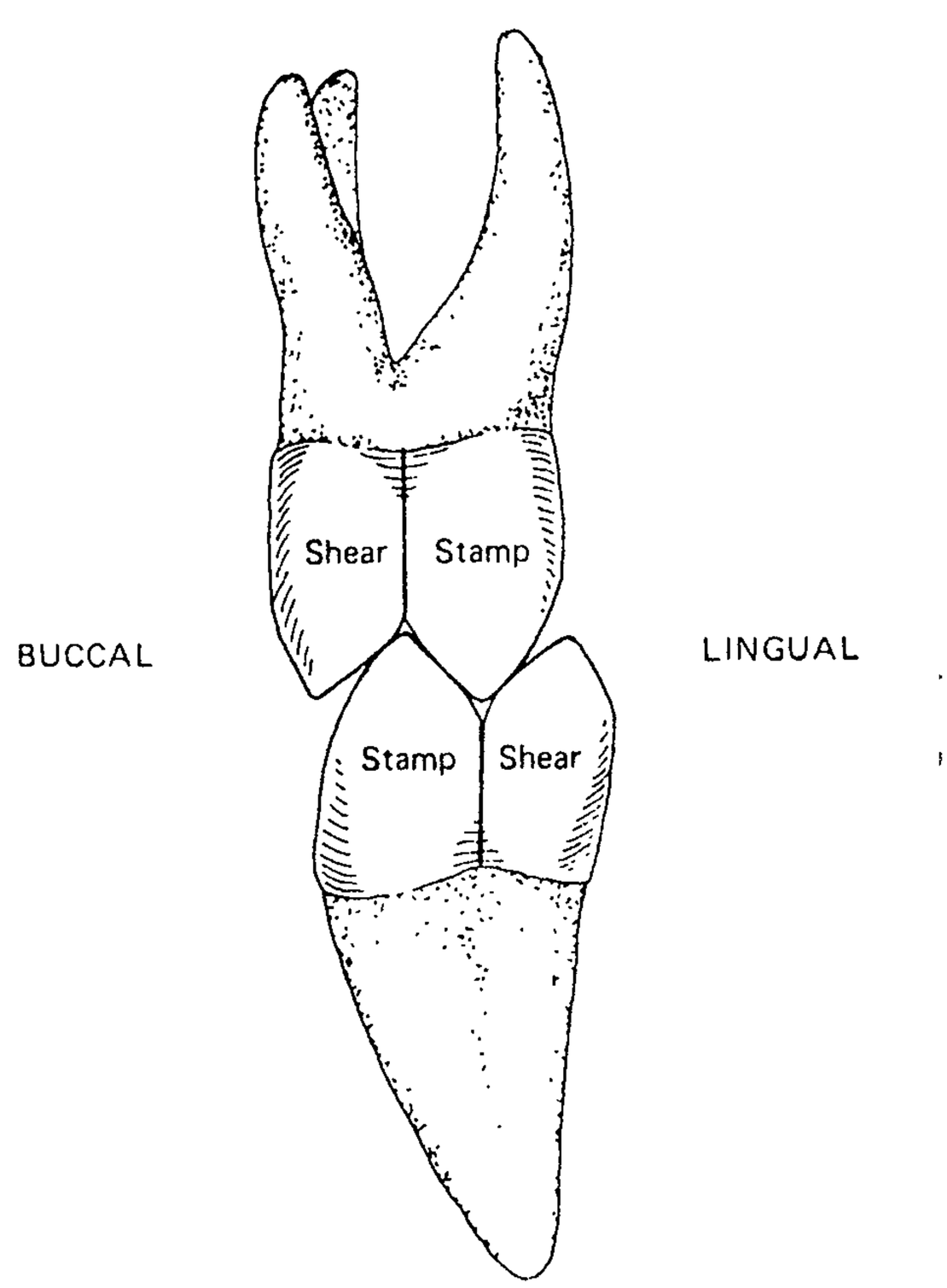

FIGURE 13. The two basic types of cusps.

(From: McHorris 1979a)

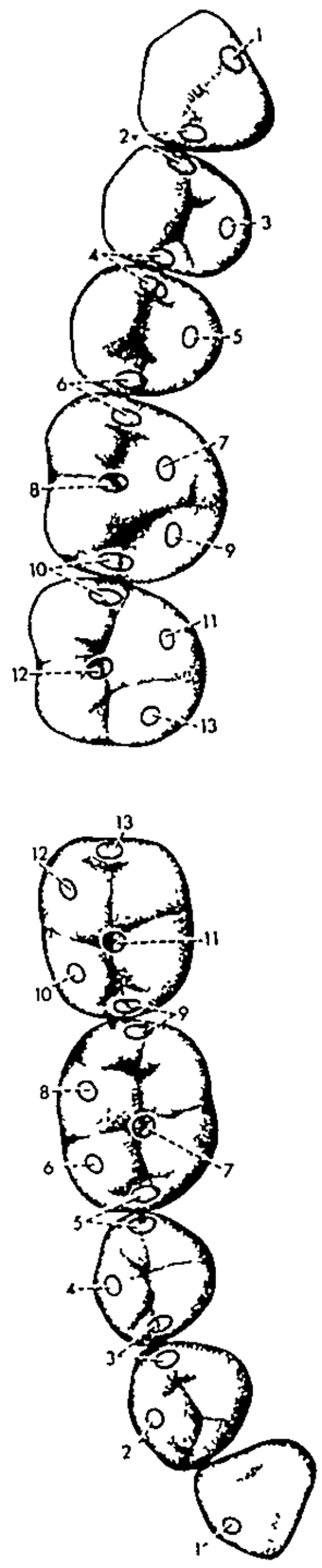

FIGURE 14. Location of centric stops.

(From Ramfjord and Ash 1971)

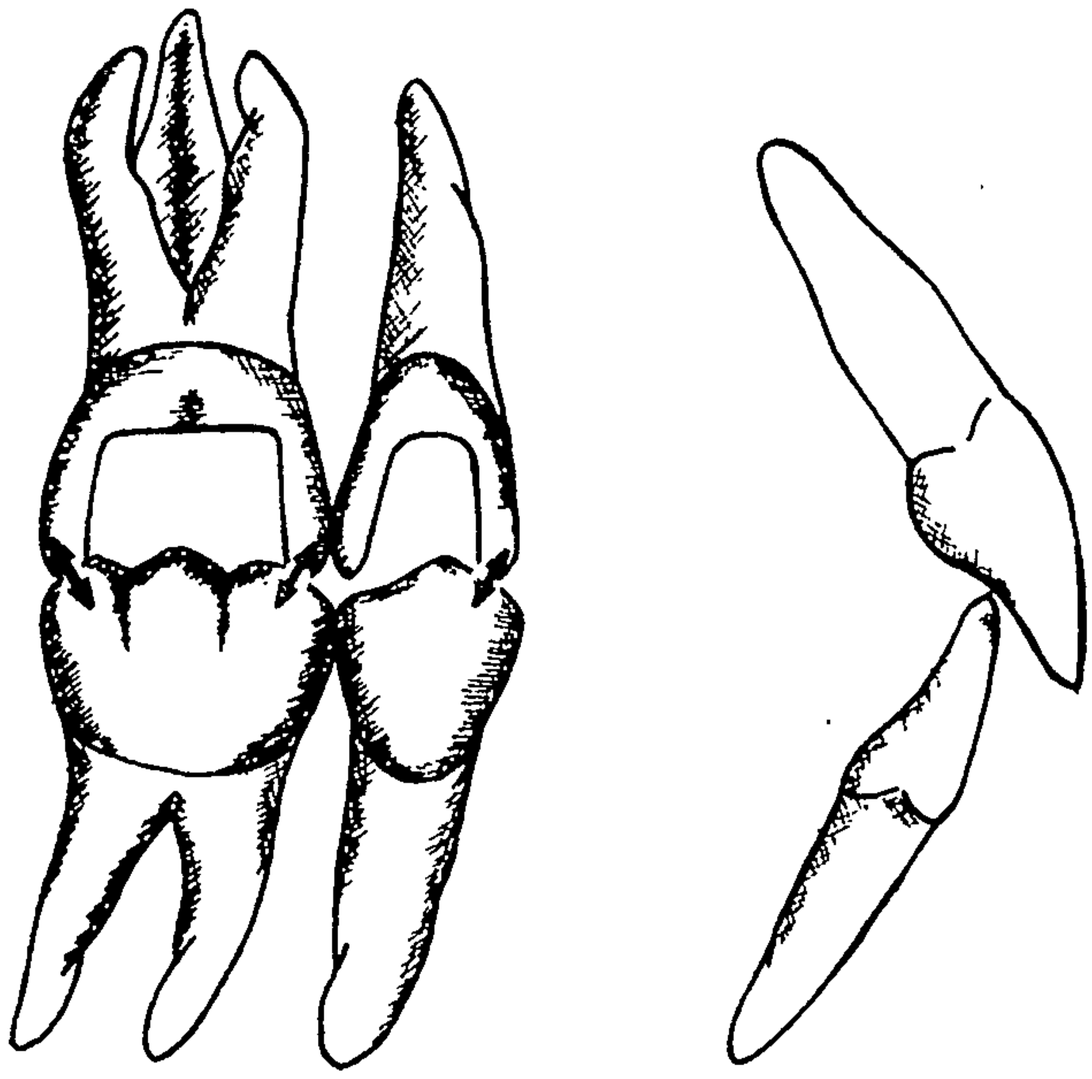

FIGURE 15. Closure stoppers and equalizers, viewed in the sagittal plane, occurring simultaneously will assure mesiodistal stability.

(From: McHorris 1979b)

Contacts which offset buccolingual movement are classified as A, B and C. The A contact is between an upper shearing cusp and a lower stamp cusp. The B contact is from an upper stamp cusp to a lower stamp cusp. The C contact is from an upper stamp cusp to a lower shearing cusp. Both A and C contacts are not absolutely necessary on each tooth as long as there is one of them to offset the forces exerted by the B contact. (Figure 16)

The pathway that the cusp travels as it leaves the fossa will be determined by the condylar guidance. Most natural teeth have grooves running in the correct direction to correspond with movements of the mandible, provided the tooth is in the correct position. Working side grooves run in the transverse direction, while non-working side grooves run in oblique direction.

4.2 OCCLUSAL INTERFERENCES AND MANDIBULAR DISPLACEMENT

Cuspal interferences are tooth contacts forcing the mandible to deviate from a physiologic movement pattern (Ahlgren and Posselt 1963). Cuspal interferences may occur in connection with habitual closure and terminal hinge closure, as well as during gliding movements (articulation). Roth (1973) says that balancing interferences cannot be divorced from those interferences that cause centric deviation because the same cusps are involved. Ahlgren and Posselt (1963), however, had failed to show any correlation between the two types of cuspal interferences. According to Bruno (1971), deflective, interceptive, or gliding contacts will introduce noxious impulses into some or all of the masticatory muscles, and these impulses may introduce changes in the neuromuscular system which controls mandibular motion.

Thompson (1956) differentiated between minor premature contacts, in which the teeth involved are thrust aside slightly, and occlusal interferences which cause displacement of the mandible. If tooth material is interposed within the vertical of the

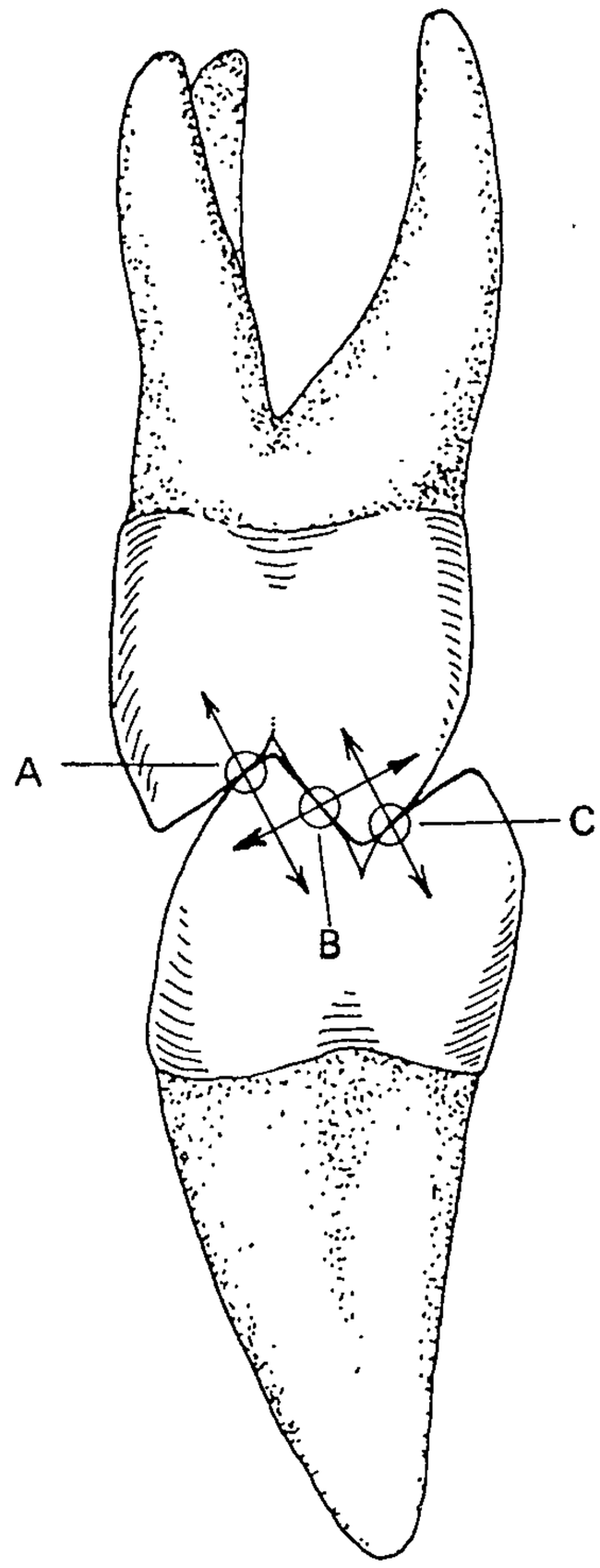

FIGURE 16. A,B,C contacts, viewed in the coronal or frontal plane, occurring simultaneously will assure buccolingual stability.

(From: McHorris 1979b)

freeway space, in such a manner as to prevent maximal occlusal contacts, the mandible will be shifted by the musculature to a position of maximal contact, which varies from its median occlusal position (Perry 1960). This movement to a displaced or eccentric position is the result of neuromuscular accommodation. Patients learn to develop a neuromuscular avoidance pattern to occlusal interferences (Roth 1973). According to Roth, it is the neuromuscular avoidance pattern that sometimes makes it difficult to locate many harmful occlusal interferences intraorally.

Weinberg (1979) believes that the existence of a deflective slide from centric relation to the acquired centric occlusion, without correlation with the temporomandibular joint radiographs, should not be indicative of specific recommended treatment. Weinberg (1980) and Perry (1960) differentiate between lateral, anterior and posterior mandibular displacements. This corresponds to unilateral or bilateral, anterior, posterior or sometimes superior displacement of the condyles. In the anterior condylar displacement centric relation is usually functional, whereas in superior and posterior condylar displacement the centric relation is dysfunctional.

According to Ramfjord and Ash (1971), occlusal interferences between centric relation and centric occlusion are more apt to create neuromuscular disharmony associated with swallowing than during mastication. Occlusal interferences laterally and protrusively to centric occlusion are apt to interfere with the muscle harmony in mastication rather than during swallowing. Forces are important during function, but they are more important during periods of non-function, since these latter forces are usually more powerful and more destructive and extend over longer periods of time (Ross 1974). Areas of contact between the mandibular and maxillary teeth should be considered from the point of view of mandibular position and excursion at the time of their occurrence, their location, size, distribution and number. Rosenthal and Burch (1975) say that patients under emotional

or psychic stress, have a tendency to clench, clamp, grind, gnash, and "doodle" with occlusal interferences. In order to do these things, certain muscles must move the mandible in such a direction as to bring the interferences into contact, and these muscles may become overstressed and painful.

4.3 OCCLUSAL INTERFERENCES IN ORTHODONTICALLY TREATED AND UNTREATED OCCLUSIONS

Little evidence has been presented in the literature about the location and nature of tooth contacts as they exist in the mouths of typical clinical patients. Anderson and Myers (1971) studied the centric occlusion contacts in thirty-two adult patients, aged 20 to 59 years. No patient had an ideal occlusion. Most of the teeth that had no occlusal contact with an opposing tooth were anterior teeth. The anterior teeth with occlusal contacts occluded on two or more inclined planes leading to a fossa, or on a combination of inclined or flat planes.

Ehrlich and Taicher (1981) recorded the location of occlusal contacts on posterior teeth, in the intercuspal position, in 29 young adults, 18 to 20 years of age, with normal tooth alignment and Angle Class I molar and canine relation, no prior orthodontic treatment, complete dentition except for some missing third molars, no pathological periodontal condition, or temporomandibular joint pain symptoms, and satisfactory oral hygiene. Three types of indentation in the green casting wax were recorded: (1) perforation of the wax, representing supracontact, (2) a translucent area, representing contact, and (3) slight indentation of the wax, representing near contact. The mean number of occlusal contacts for each patient was 79. The range was from 40 to 110 occlusal contacts. Contact was present in 79.6% of teeth, supracontact in 7.9%, and near contact in 12.5%. The maxillary first molar showed the largest number of contacts (20.9%), while the mandibular first premolar had the least number of contacts (5.8%). There was a predominance of supracontacts in the second molars (33%).

Most of the contacts were present on the inner aspect of the supporting cusps. Only a few contacts were present in the central fossa and marginal ridges. Ehrlich and Taicher (1981) conclude that all participants had a morphologically sound occlusion, but none showed an ideal occlusion. Therefore, morphologically sound occlusion should not imply maximum tooth contacts. It is conceivable that functional adaptation may accompany occlusal and interproximal attrition.

McNamara and Henry (1974) investigated the variation in tooth contacts at centric occlusion and centric relation, using 15 men, 16 to 17 years of age, as subjects. All had well-developed, caries-free, unrestored dentitions, except for unerupted third molars. A positional difference between centric occlusion and centric relation was demonstrated in all subjects. In all subjects, a dramatic decrease in contacts of opposing teeth occurred as the mandible changed position from centric occlusion to terminal hinge contact. Differences in facial height between the two positions ranged from 0.1 to 2.92 mm, while the anteroposterior difference ranged from 0.98 to 2.86mm. No correlation was established between the anterposterior positions and vertical differences at centric occlusion and terminal hinge contact. Most subjects demonstrated midline deviation on retrusion.

Studies on post-orthodontic occlusal problems are few, and no two studies are the same. Aubrey (1978) believes that prematurites are always present to some degree in the finished orthodontic case, regardless of how well it is treated. Mathews (1967) says that, where extensive orthodontic tooth movement has been necessary to correct the occlusion, it is not too surprising that prematurities in tooth contact would be found. According to Watson (1980) there are three most frequently involved areas in occlusal interferences. These are the lingual cusp of the upper second molar, the oblique ridge and lingual cusp of the upper first molar, and the mesiobuccal incline of the lingual cusp of the upper premolars. Roth (1976) suggested that the most common areas of centric prematurity in post-orthodontic cases are:

A. The buccal cusp of the mandibular first or second premolar with the mesial inner incline of the lingual cusp of the maxillary first or second premolar.
B. The mesial inner incline of the distobuccal cusp of the maxillary first molar with the distal outer incline of the middle buccal cusp of the mandibular first molar.
C. The mesial inner incline of the mesiolingual cusp of the maxillary first molar with the distal inner incline of the middle buccal cusp of the mandibular first molar.
D. The mesial inner incline of the maxillary second molar with the distal inner incline of the mesiobuccal cusp of the mandibular second molar.
E. The lingual surface of the maxillary mesiolingual cusp of the first and second molars with the distal inner incline of the mesiolingual cusp of the mandibular first and second molars.

Heide and Thorpe (1965) studied ten orthodontic cases selected at random after treatment was terminated. The ten cases were studied before and after orthodontic correction, by careful examination of the occlusion as seen by the conventional orthodontic models, and later by the centric relation of the plaster casts mounted on an articulator. In every case the centric relation and centric occlusion were not identical, and the severity of the "skid" being governed by the points of initial occlusal contact in centric relation. In many of the Class II malocclusions studied, examination of the models in centric relation gave evidence that the assumption of orthodontic success in posterior bite correction was erroneous, and these cases showed tendency toward still being Class II.

Cohen (1965) examined forty orthodontically treated patients and thirty-six persons with normal occlusions for the purpose of determining whether or not there were any occlusal interferences in centric relation and habitual bite. The mean age of the treated patients was 16.4 years, and that of the untreated patients was 16.1 years. The frequency and location of occlusal prematurities in the two groups studied showed a striking similarity. The length of time betwwen completion

of treatment and the date of the investigation was not significant with respect to the number of prematurities recorded. A glide or shift of the mandible following initial contact of the teeth was found in 75% of the treated and in 80% of the untreated patients. Prematurities in retruded position were found in 90% of the treated and 81.7% of the untreated patients. Prematurities in habitual bite were found in 92.5% of the treated and 94.4% of the untreated patients.

Ahlgren and Posselt (1963) carried out a functional analysis of 23 orthodontically treated patients with a mean age of 14 years, and 120 pre-orthodontic malocclusion patients with a mean age of 11 years. Cuspal interferences were present in 55% of pre-orthodontic cases, and in 61% of post-orthodontic cases. The distribution according to type of malocclusion (Angle) was fairly even in the untreated group and, thus, there appeared to be no relation between a certain morphologic class and functional malocclusion. A noticeable fact was, however, the strong connection between crossbite occlusion and cuspal interferences. This has clinical significance because it is relatively harmless from a morphological standpoint. Nevertheless, it may constitute a severe occlusal disharmony.

Gazit and Lieberman (1973) made a comparative study of the occlusion of orthodontically treated and untreated dental students, using the intercuspal total surface contact area registration as a method of evaluating their occlusion. The students were divided into four groups:

A. Treated orthodontically with the removal of four premolars
B. Treated orthodontically without extractions
C. Untreated good occlusion
D. Untreated poor occlusion.

Compound bites in intercuspal contact positions were obtained from all students, mounted on cardboard sheets, and transilluminated. The average light meter readings obtained from the first three groups were statistically higher than

that of the fourth group. In this respect, orthodontic treatment had produced results which compared favorably to those extant in the good occlusion group. Both the extraction group and the malocclusion group registered considerably higher percentages of non-working side interferences than did the remaining two groups, particularly in the area of the first molar and the remaining premolar. These are the teeth closest to the extraction site, and the teeth whose axial inclinations and buccolingual positions are often the most affected by orthodontic corrective procedures. Generally, the first three groups exhibited the most common non-working interferences in the area of the second molar, with the first molar and premolars next in frequency. The malocclusion group differed in this aspect, showing no consistent gradation in the occurrence of non-working interferences among the different teeth. The four premolar extraction group showed the highest percentage of clenching and temporomandibular joint pain.

CHAPTER 5

Effects of Occlusal Disharmony

5.1 OCCLUSAL CONSIDERATIONS IN PREVENTIVE CARE

The recognition that crisis care in medicine is the least effective and most expensive form of therapy has focused the attention of health providers on prevention (Rubin 1980). Similarly, in dentistry, the understanding of the pathology of dental caries and periodontal disease has led to a preventive orientation: control of plaque. Why, then, should the possible sequelae of inadequate functional occlusion be left to crisis care? Why should pain be the only indicator for treatment? Should we not aim for prevention in this aspect of health also? (Figure 17)

The orthodontist has received criticisms by some facets of the dental profession for practising iatrogenic dentistry, resulting in dysfunctional symptoms in the patient (Williamson 1976). According to Wright (1970), our dental colleagues are becoming ever more aware of the problems that arise in cases, orthodontically treated by methods and philosophies that are mechanically rather than biologically oriented. Thompson (1956) claimed that all orthodontists have, at some time, unknowingly been guilty of converting an excellent physiological occlusion, but one that was in malocclusion, into a better anatomical occlusion, to the detriment of the physiological occlusion. The orthodontist must be constantly alert for iatrogenic factors in his treatment procedures (Perry 1969). Clinicians should note that, through the patient's adaptive mechanism, nature makes amends for its own imperfections, but it should not provide cover for the orthodontist's short comings (Timms 1969).

From the beginnning, when the first separator is placed, to band cementation and the movement of teeth, the entire occlusal scheme is altered (Barnett 1978). The orthodontist moves teeth into extraction sites, alters the vertical dimension, and puts inclined planes against cusps in the most traumatic fashion, and only in a certain few instances does he see immediate evidence of dysfunctional sequelae (Perry 1976). Thus, is it not conceivable that the orthodontist is

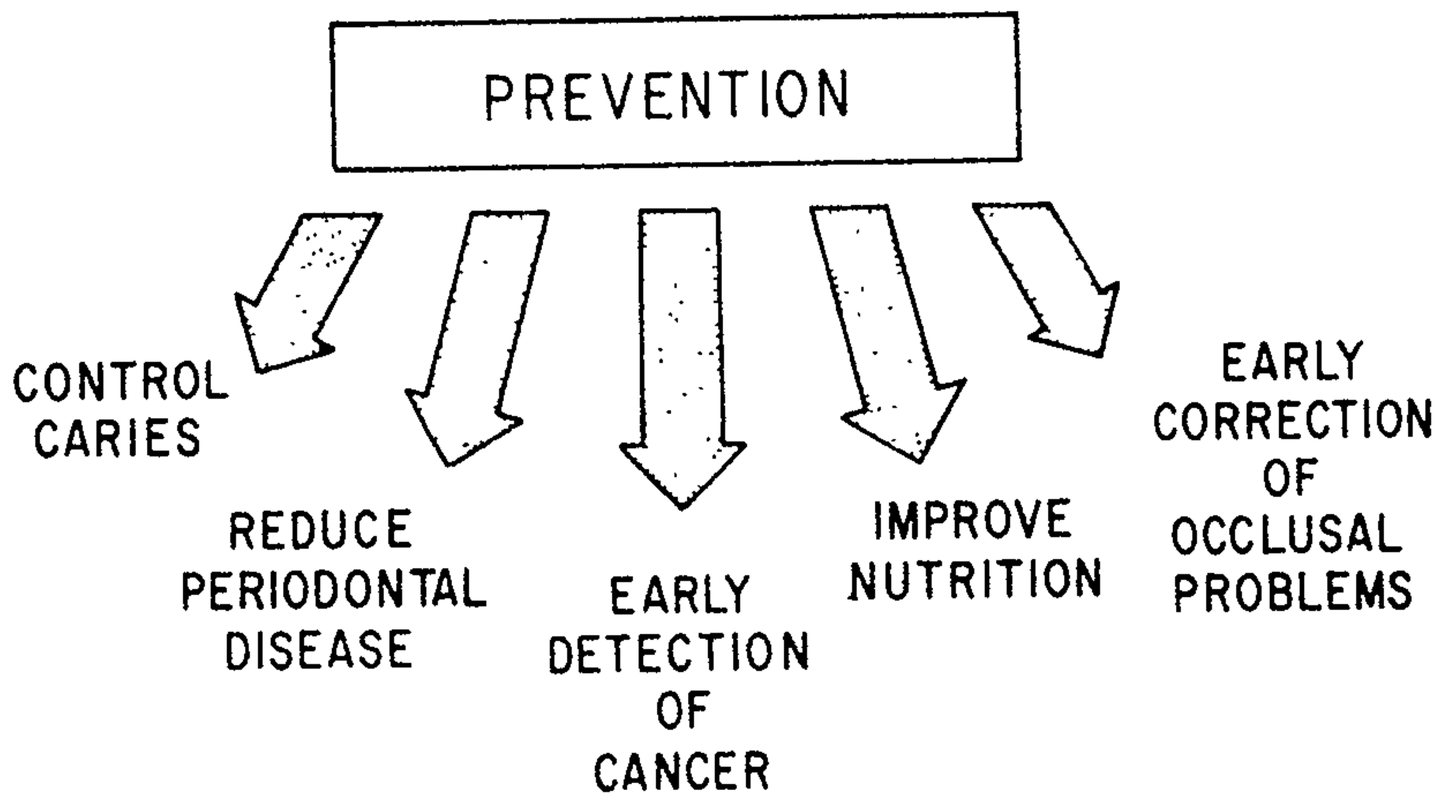

FIGURE 17. The role of prevention in total patient care.

(From: Rieder 1972)

more difficult to impress with the consequences of functional occlusion concepts that are accepted by other dental practitioners?

We acknowledge that the growing child has a developing muscle, skeletal and nervous system, which is labile and very adaptive (Perry 1976). At that age, they are so adaptable that they can accommodate to almost any occlusal discrepancy that the orthodontist may create. However, the patient grows up and becomes less and less adaptable (Barnett 1978). It may take some years for abnormal functional conditions to take their toll and be recognized as pathologic states of the teeth and supporting tissues, temporomandibular joints, and musculature. Efforts are then directed toward repair and replacement, and this is often too little too late (Thompson 1962).

Zarb and Thompson (1970) write that the components of the human masticatory system are rarely in harmony, but the system demonstrates a remarkable adaptive range. It will continue to function in spite of loss or damage, always within the confines of the tolerance level of the particular system. Dysfunction of any one unit in the system is reflected in all the other units (Bruno 1971). Because of the confusion relative to the aetiology of occlusal pathologic conditions, there has almost been a fear of providing any treatment for a beginning occlusal problem (Rieder 1972). Consequently, incipient occlusal problems are not considered by some to be indicative of any treatment requirement. Intervention is delayed until there is a multitude of signs and symptoms, or perhaps an extremely complicated disorder or active disease state. Unfortunately, we cannot predict which patients will have problems in the future. However, if orthodontists are to prepare patients for their dental future, they must understand the main problems that adults have regarding their dental health, and also what relieves these problems (Chiappone 1975). As age increases, the natural course of events leads to the development of increased signs and symptoms of disease (Rieder 1972).

5.2 OCCLUSAL CONSIDERATIONS IN STABILITY

The stability of orthodontic treatment seems to depend mainly on the extent to which the occlusion can be brought into functional balance with the individual craniofacial skeletal pattern, and the mode of breathing, swallowing, speech and mastication (Van Beek, Myrberg and Timmers 1976). King (1974) studied relapse of orthodontic treatment, and found that posterior cuspal interdigitation contributed both to anteroposterior and lateral stability. Lack of it seemed to complement any predisposition to relapse on the basis of other unfavourable factors. Anteriorly, satisfactory incisor and canine relationships contributed to stability of overbite, overjet and rotations. Roth (1981c) believes that, in posttreatment orthodontic cases, the anterior teeth will tend to move to accommodate mandibular movement, if anterior tooth positions interfere with these movements. Excessive lateral stress on the canines may cause lingual movement of the lower canines and resultant lower anterior crowding, and/or labial movement of the maxillary canines. If the central incisors become the only teeth in contact in an incisive relationship, or there is insufficient crown inclination of the maxillary central incisors, the chances of their relapse labially are enhanced. McHorris (1974) says that, due to the anterior component of force, the mesial drift of all teeth can occur more rapidly in mouths with deflective occlusions and when the incidence of bruxism is high. This existing force must be neutralized by proper organization of posterior interocclusal contacts.

In the presence of occlusal interferences, it is usually the weakest link in the chain that tends to break down (Roth 1976). Many times the weakest link in the post-orthodontic case is the stability of the tooth positions. This will tend to break down before the periodontium, the temporomandibular joints, or before occlusal wear occurs. In this sense, relapse of tooth positions or tooth movement after orthodontic treatment, could be considered, at least to some extent, to be a symptom or sign of occlusal disharmony.

Riedel (1960) says that in his opinion, functional interference as a cause of relapse in treated orthodontic cases, has been overemphasized. Hyperfunction or complete lack of function are probably most undesirable from the standpoint of normal tissue and bone health, but teeth do not seem to move in response to hyperfunction unless considerable loss of bony support or root length has occurred. Proffit (1978) says that forces from dental occlusion are of very high intensity but short duration, and as such are not as important in determining the final position of teeth as the resting pressures of lip and cheek and tongue, and forces produced by metabolic activity within the periodontal membrane.

Obviously, occlusal dynamics is not the total answer to stability of the orthodontic case, but it is one of the factors that must be considered in the ever-elusive quest for the answer to post-orthodontic relapse (Roth 1976).

5.3 OCCLUSAL CONSIDERATIONS IN TEMPOROMANDIBULAR JOINT DYSFUNCTION

The aetiology of mandibular joint syndrome is considered to be multifactorial (McNamara 1976a). Of importance seem to be cuspal interferences, emotional instability, socio-economic conditions and impaired state of general health (Mohlin, Ingervall and Thilander 1980). Several concepts are necessary to explain the symptoms (McNamara 1976a):

A. Mechanical displacement of the condyles
B. Muscle imbalance due to hypokinetic disease
C. Neuromuscular disharmony of the masticatory components
D. Psychophysical hyperactivity or spasms of the masticatory musculature
E. Psychological factors which lead to parafunctional mandibular movements.

Weinberg (1979) states that clinical and electromyographic evidence of a direct cause-and-effect relationship between occlusal interferences and temporomandibular joint pain-

dysfunction syndrome is conclusive. However, this does not imply that occlusion is the only factor, or that it is the main causative agent in every patient. A patient's occlusion can force the condyles to be displaced posteriorly, superiorly or anteriorly. The temporomandibular joint is called upon to physiologically adapt to the malalignment of the condyle in the fossa and still function. Joint dysfunction or pathological changes develop when this "adaptive ability" is exceeded.

It seems probable that both morphological and psychological factors are associated with the development of the temporomandibular joint pain-dysfunction symptoms (Kirveskari 1971). The absence of wear appears to have a positive rather than negative effect on structural masticatory efficiency, but a detrimental effect is ascribable to the increased risk of positional instability of the mandible during the unconscious swallow. The acceptance of this latter form-function disharmony as the prime aetiologic factor causing temporomandibular joint pain-dysfunction does not imply that unconscious tooth clenching and grinding cannot arise from psychic reasons alone. It implies, however, that psychogenic tooth clenching and grinding without the morphological factor are not pathogenic. This is in agreement with McNamara's (1976a,1977) findings on the median occlusal position.

Dawson (1974) emphasizes the importance of "host resistance". He says that emotional stress is a factor in altered host resistance. Lerman (1973) writes that some individuals are psychologically predisposed to magnify the stress-generating potentials of their life situation. Mikhail and Rosen (1980) believed that the key factor is the patient's ability to adapt to the occlusal disturbances, as determined by the individual's psychologic state. Thus, the pain-dysfunction depends on the intensity of the initiating factor (occlusion), and the state of resistance or adaptation, as determined by psycholgic parameters.

Weinberg and Lager (1980) state that the scientific method

cannot be applied to research of temporomandibular pain-dysfunction syndrome, because the human variables cannot be isolated. In addition, the multi-causality of its aetiology prevents individual study. Multi-causality has been established by the clinical response to palliative therapy, as well as occlusal adjustment. The onset of pain can be triggered by sudden occlusal changes, as well as acute stress situations. Most often, a combination of aetiologic events produce the symptoms; however, the aetiologic profile will vary from patient to patient, in that one patient might have a very strong stress factor while in the next patient, occlusion is the predominant cause. Weinberg (1974) believes the problem is not to decide which single factor caused the symptoms, but rather to understand the inter-relationship of the many factors operating, and their timing.

According to Perry (1973), if orthodontists are to deserve their expected position in the health service team, they must recognize, eliminate, or correct factors contributing to temporomandibular joint dysfunction. Perceptive diagnostic interception will spare the patient pain and discomfort. The clinician will only recognize those conditions he has been trained to recognize, and will only see that for which he looks (Roth 1976).

Solberg (1979) provides an excellent summary of the clinical evaluation of occlusion-related pathosis. Klineberg (1980c) provides detailed history and examination forms for the detection of oro-facial pain dysfunction. He says that pain may arise from other sites in the head and neck, and correct identification of the aetiology of pain problems depends on skilful differential diagnosis. Scheman (1980) provides a table for differential diagnosis. McNeill et al (1980) give a classification of temporomandibular joint disorders:

I. Temporomandibular joint disorders of organic origin
    A. Articular disturbances
        1. Disk derangements
            a. Disk dysfunction
            b. Disk displacement
            c. Disk dyscrasias

2. Condylar displacement
3. Inflammatory conditions
    a. Synovitis
    b. Diskitis
    c. Capsulitis
    d. Contusion
    e. Rupture
4. Arthritidies
    a. Osteoarthritis (arthrosis)
    b. Rheumatoid arthritis
    c. Polyarthritis (i.e., gout, lupus, Reiters Syndrome)
    d. Rheumatoid variants (i.e., psoriatic, juvenile)
    e. Infectious arthritis
5. Ankylosis
    a. Fibrous
    b. Osseos
6. Fractures
7. Neoplasias
    a. Chondroma
    b. Osteoma
8. Developmental abnormalities
    a. Hyperplasia
    b. Hypoplasia
    c. Agenesis

B. Nonarticular disturbances
    1. Neuromuscular conditions
        a. Myofascitis (muscle tenderness)
        b. Contracture (mechanical shortening)
        c. Trismus/spasm (reflex splinting)
        d. Dyskinesia (weakness and incoordination)
    2. Dental occlusal conditions
        a. Unstable occlusion (structural imbalance)
        b. Premature posterior tooth contacts (posterior fulcruming)
        c. Lack of posterior occlusal support
        d. Distal thrust to mandible
    3. Disturbances involving referral of secondary symptoms
        a. Latent myofascial tenderness
        b. Active myofascial trigger points

II. Temporomandibular joint disorders of nonorganic (functional) origin
    A. Myofascial pain-dysfunction (MPD) syndrome
    B. Phantom pains
    C. Positive occlusal sense
    D. Conversation hysteria
III. Temporomandibular disorders of nonorganic origin combined with secondary organic tissue changes
    A. Articular
    B. Nonarticular
        1. Neuromuscular
        2. Oral
            a. Teeth
            b. Periodontium
            c. Soft tissue

Klineberg (1980c) states that one or both temporomandibular joints may be involved in a functional disturbance of the masticatory system, althogh there is usually unilateral joint dysfunction. The muscles and joints may contribute together or independently to the pain dysfunction. Wasson (1979) says that patients with temporomandibular joint damage will deviate the mandible to the side of the painful joint when opening, because the mobility of the affected side is reduced. In contrast, the patient with temporomandibular joint pain-dysfunction syndrome generally deviates the mandible to the side opposite that of the painful joint, because the pain, which is due to subluxation of the condyle fulcruming over an interference, makes the lateral pterygoid on the affected side hypertonic.

Epidemiological investigations have shown that at least 50% of the population have some form of temporomandibular joint pain-dysfunction problems, and that 25% of these individuals are in need of treatment (Mohlin and Kopp 1978). The incidence of symptoms and signs of temporomandibular joint dysfunction varies from study to study. Weinberg and Lager (1980) say that symptoms related to function are pathognomonic of temporomandibular joint pain-dysfunction syndrome. In their study, 67% of the 138 patients referred

to them with temporomandibular pain-dysfunction syndrome had an increase in pain with some type of function, such as when chewing, after meals, or after talking. Pain on opening, history of trismus, and a pattern of occurrence were other diagnostic symptoms. Ear symptoms were present in 48% of patients in the study. Joint noises were present in 68% of the patients in the study, involving clicking, popping and crepitus, in that order. Of the patients in this study, 21% reported injury as a trigger mechanism, 24% reported dental treatment as a trigger mechanism, 26% reported stress as a trigger mechanism, while 36% of the patients in the study reported no trigger factors. The dental trigger factors included orthodontic treatment, restorations, dental surgery, partial dentures and complete dentures, in that order of occurrence. Although 57% of patients in this study had a history of trismus at some time during their symptom period, this usually occurred in the early stages. Most of the chronic temporomandibular joint pain dysfunction patients could open their mouths between 27 and 53mm, and only 16% of the patients in this study were limited in opening to less than 26mm. Lateral deviation on opening was found in 17% of the patients in the study. The incidence of centric relation coinciding with centric occlusion in the patients in this study was 31%, which is much higher than the classically accepted 10% in symptom-free patients. Correlation with TMJ radiographs, however, revealed that 60% of this 31% of patients with clinically coincident centric relation and centric occlusion had posterior condylar displacement, 25% had anterior displacement and 15% were in the middle of the fossa.

Helkimo (1974b) performed an epidemiological investigation on Lapps in Northern Finland. He found that the subjective symptoms of dysfunction, as measured by his Anamnestic Dysfunction Index, were 43% of subjects symptom-free, 31% of subjects with mild symptoms, and 26% of subjects with severe symptoms. The age group was 15 to 65 years. This study followed on from a preliminary report (Helkimo,

Carlsson, Hedegard, Helkimo and Lewin 1972), and a preliminary epidemiological investigation of symptoms of dysfunction (Helkimo 1974a). Helkimo found that 70% of the Lapps in his study had no impairment of mandibular mobility, as measured from his Mobility Index, and only 3% had marked impairment. The function of the temoporo-mandibular joints was impaired in 60% of persons, and the joints were tender to palpation in 45% of persons. In 66% of the persons, the masticatory muscles were tender to palpation, with dominance of the temporal and lateral pterygoid muscles, while 30% of the subjects had pain on movement of the mandible. According to Helkimo's Clinical Dysfunction Index, 12% of subjects in the study were clinically symptom-free, 41% had mild symptoms, 25% had moderate symptoms, and 22% had severe symptoms. His evaluation of their occlusion, by his Index for Occlusal State, showed that none had a morphofunctionally normal occlusion, 14% of the subjects had some mild disorder, while 86% had severe disorders. The average number of teeth per subject was 14, 10 of which had antagonistic contact. Twenty-two percent of the subjects were edentulous and 15% had complete upper and lower dentures. Occlusal interferences were found in 69% of subjects. Thirty-two percent of persons in the study had a lateral slide greater than $\frac{1}{2}$mm from retruded to intercuspal positions, and 34% had interferences on the balancing side. In the comparison between the Anamnestic and Clinical Dysfunction Indices (Helkimo 1974b), it was found that everyone who, in the history, had described their symptoms as severe, also had at least some clinical symptom, 75% of the subjects had at least one severe clinically manifest symptom, and 44% of subjects had two or more such severe symptoms. Of those individuals who, according to the history, were subjectively symptom-free, only 18% were also clinically symptom-free.

Agerberg and Carlsson (1972) investigated a random sample of 1106 individuals, aged 15 to 74 years, by questionaire. They found that 24% of the subjects reported facial pain and headache, 12% reported pain on wide opening, and 39%

reported range of mandibular movement impaired. Women sort advice more often than men, and this, they say, is the reason why the incidence of temporomandibular pain-dysfunction is often reported to be higher in women. Weinberg and Lager (1980) also believe the incidence is not necessarily sex-related.

Hansson and Nilner (1975) studied 1069 persons working in a ship-building yard in the south of Sweden. From the clinical history they found that 6% of subjects reported difficulty in opening the mouth wide, 23% reported clicking in the temporomandibular joint, 18% reported frequent headaches and 7% reported pain in, or in front of, the ears. From the clinical examination they found clicking of the temporomandibular joint in 65% of the persons in the study, tenderness of the temporomandibular joint to palpation in 10% of subjects, severe tooth abrasion in 12% of subjects and mild tooth abrasion in 66% of subjects. Weinberg (1980) found that joint noise was present in approximately 85% of acute temporomandibular joint pain-dysfunction patients, compared to an incidence of 39% in the normal population. Hansson and Nilner (1975) also found tenderness to palpation of one or more muscles in 37% of patients in their study. Lateral pterygoid and temporalis showed the highest frequency of tenderness. Weinberg (1980) says that the lateral pterygoid, insertion of temporalis and masseter muscles are the most often involved. Zarb and Thompson (1970) agree with this. The distribution of subjective pain location, according to the study of Weinberg and Lager (1980), is shown in Figure 18. The incidence of palpatable pain and its distribution, from the same study, is shown in Figure 19. Klineberg (1980c) shows methods for extra-oral palpation and intra-oral palpation of these muscles.

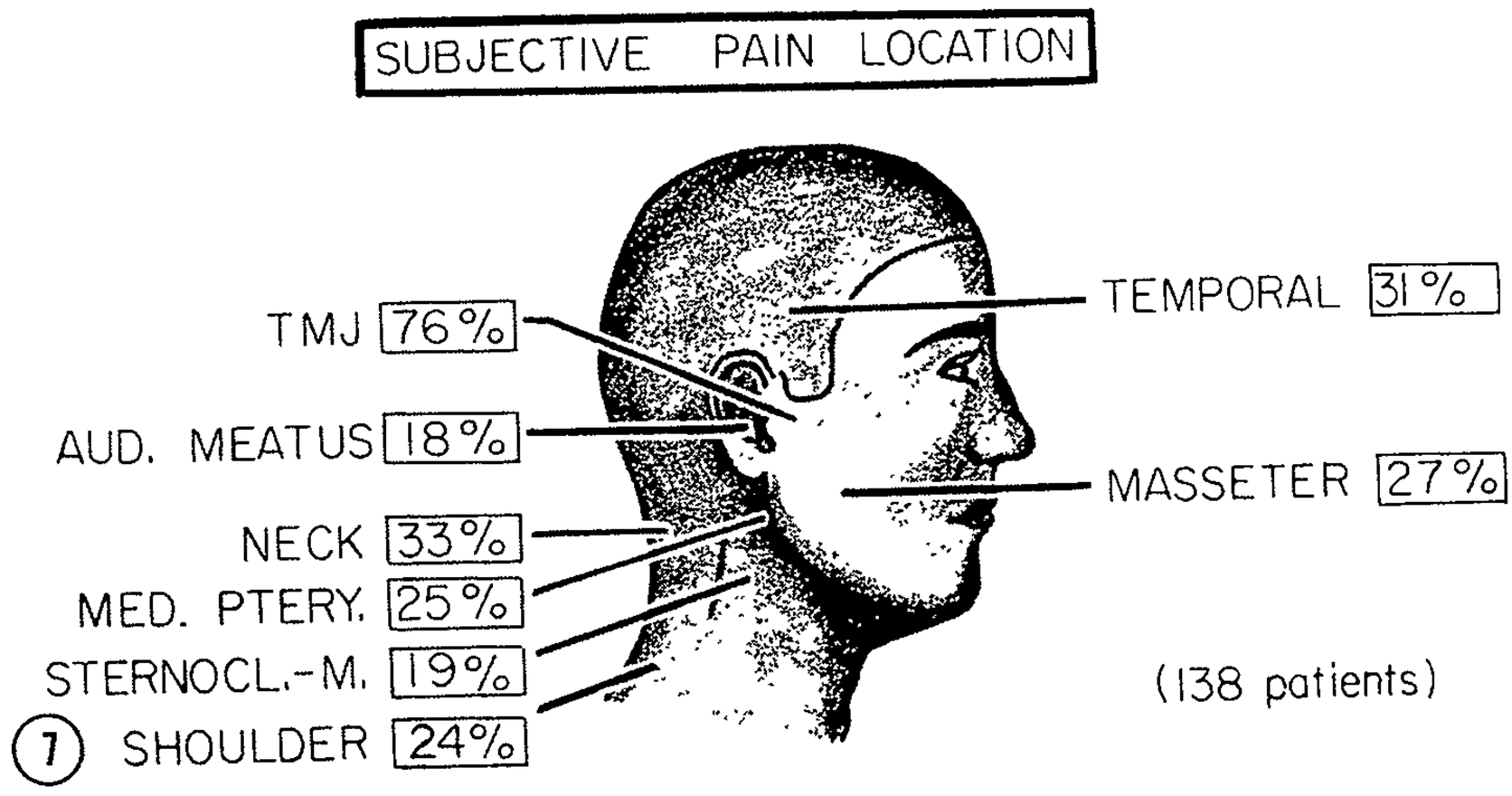

FIGURE 18. Incidence of subjective pain symptoms on the basis of location.

(From: Weinberg and Lager 1980)

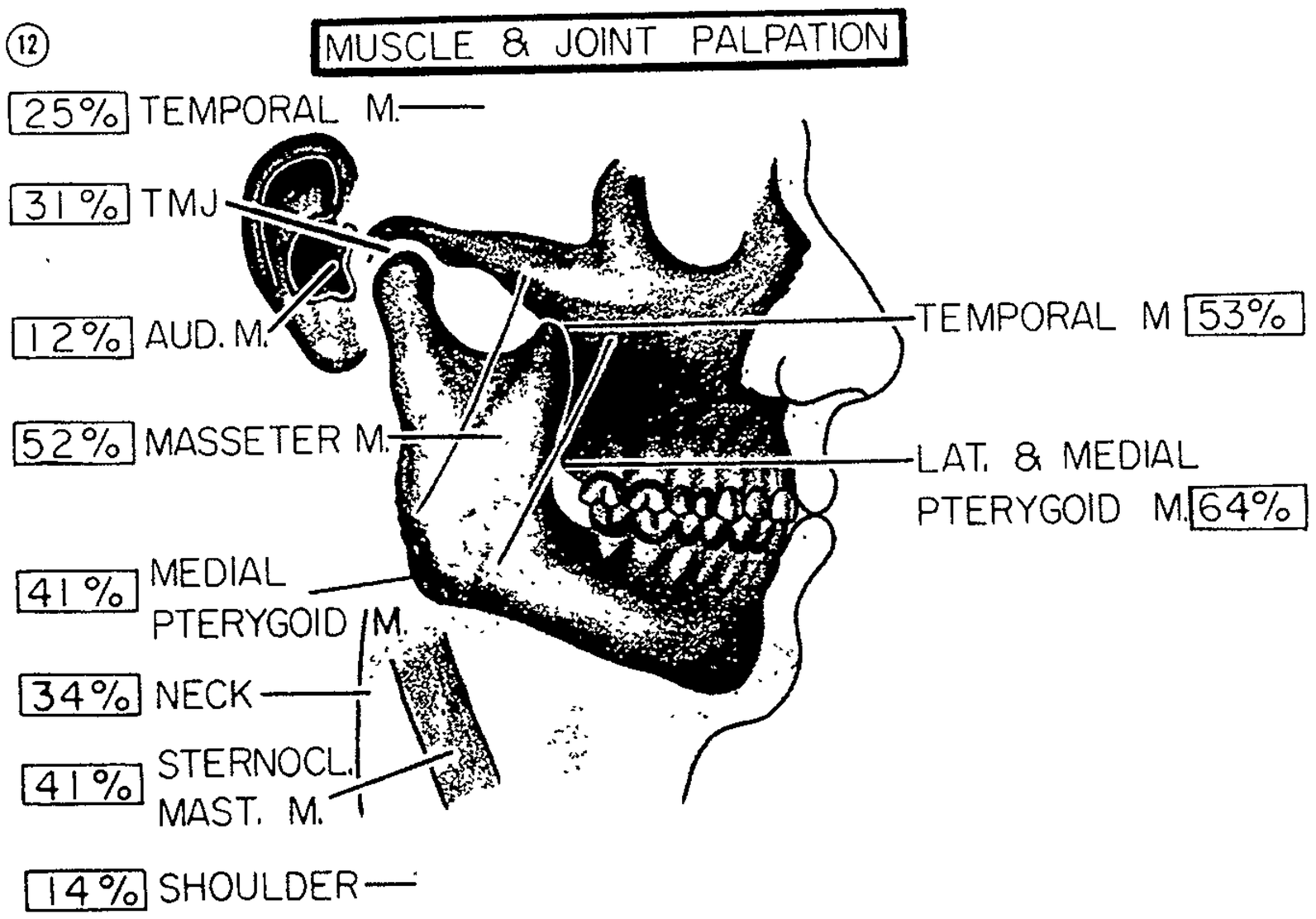

FIGURE 19. Incidence of pain from muscle and joint palpation.

(From: Weinberg and Lager 1980)

Rosenthal and Burch (1975) believe that there is a relationship between dysfunctions and supracontacts (occlusal interferences):

A. Unstable contacts in centric occlusion. When a patient gently closes the teeth in centric occlusion and the teeth on one side of the mouth contact slightly less than those on the other, proper proprioceptive feedback on the side of light contact does not occur. When patients with this type of occlusal pattern are under stress, they have a tendency to exert more muscular contraction on the side of light or no contact to bring the teeth firmly together. As a result, the elevator muscles on the side of light contact are overworked, and become tender to palpation. The muscles involved are the masseter, temporal (anterior and middle fibres), and the medial pterygoid (Figure 20).

B. Centric relation occlusal interferences. When patients are under stress, they may tend to grind retrusively from centric occlusion against the occlusal interferences. As a result, the muscles which retrude the mandible (digastric and posterior fibres of the temporal muscles) become overstressed and tender (Figure 21).

C. Nonworking supracontacts. In a patient who has a balancing side interference and who has been grinding against it, both of the lateral pterygoid muscles, together with the elevator muscles on the side opposite the balancing interference, are usually found to be tender (Figure 22).

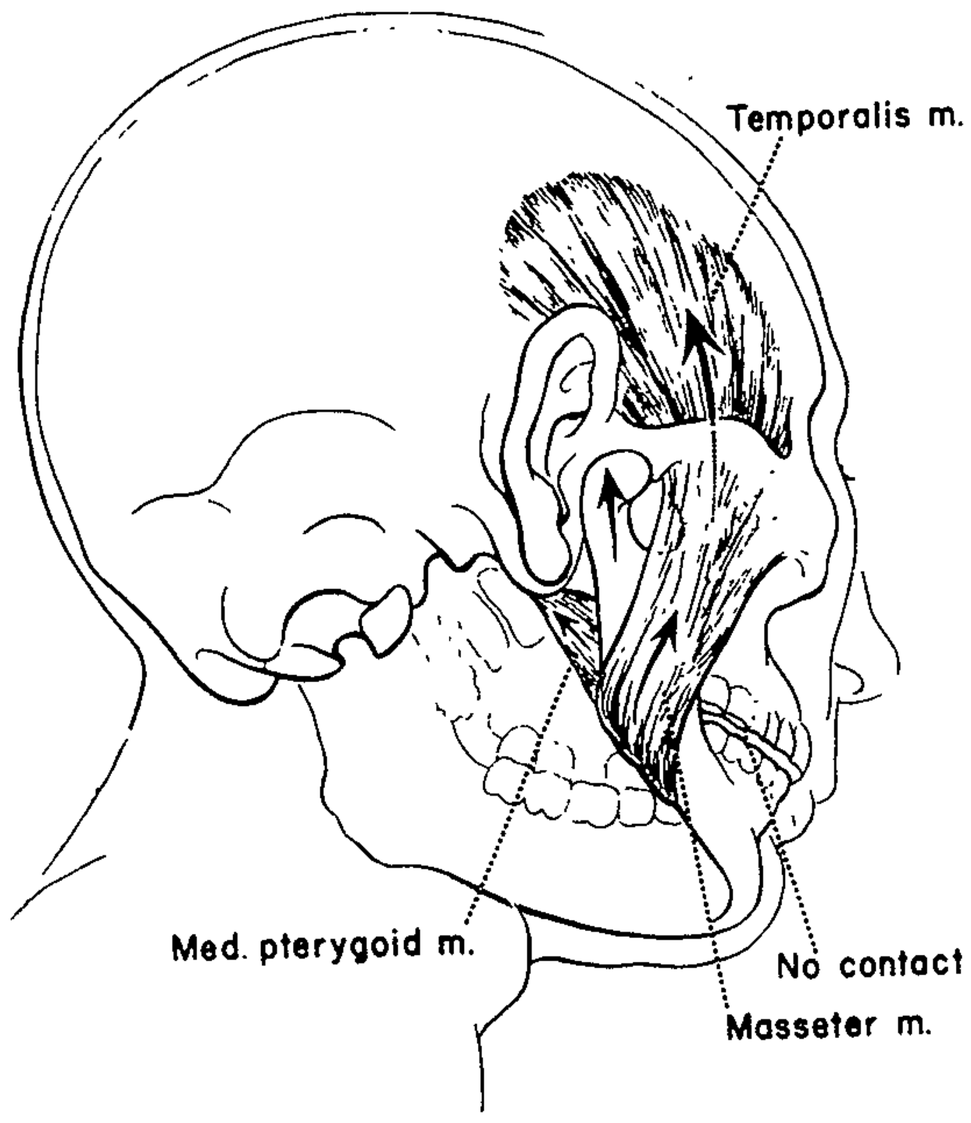

FIGURE 20. Muscular action with unstable contacts in centric occlusion.

(From: Rosenthal and Burch 1975)

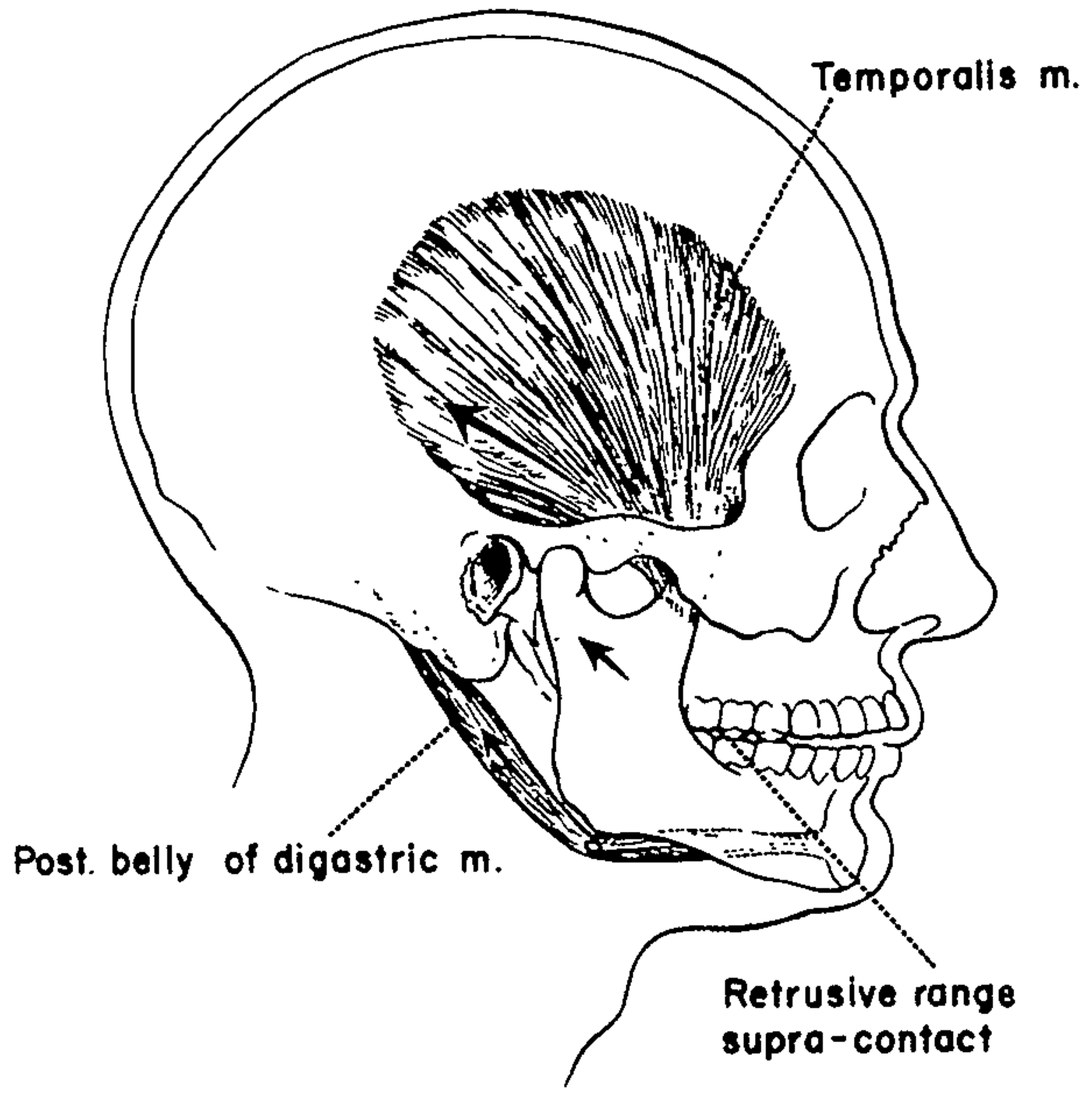

FIGURE 21. Muscular action with retrusive occlusal interferences.

(From: Rosenthal and Burch 1975)

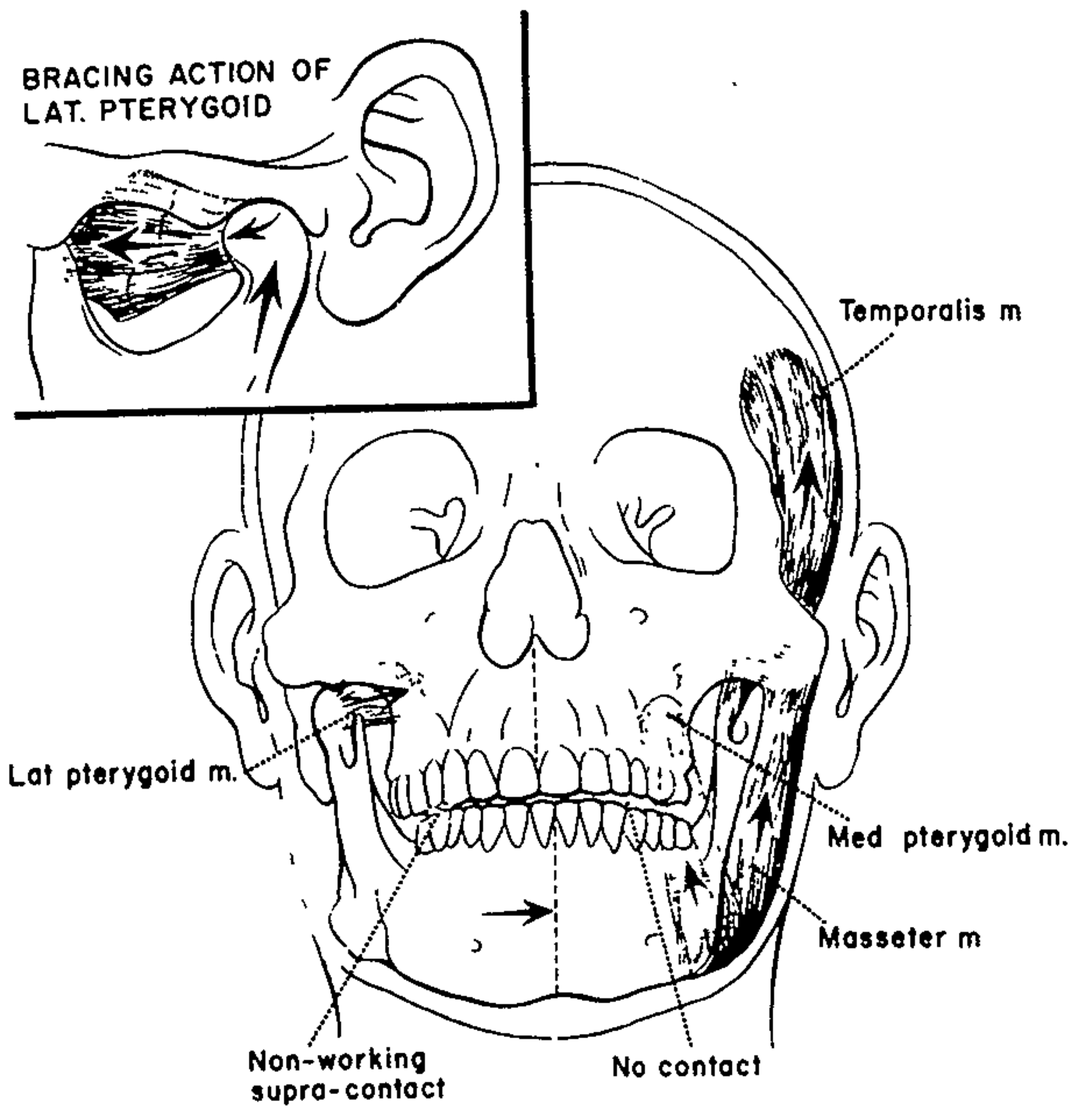

FIGURE 22. Muscular action with nonworking occlusal interferences.

(From: Rosenthal and Burch 1975)

Solberg, Flint and Branter (1972) evaluated the anxiety level and occlusal disharmonies of matched symptom and control groups, and speculated that the symptom population consists of a number of subgroups, which would account for the weak relationship between pain-dysfunction and anxiety. Both groups had premature (interceptive or deflective) cuspal contacts at the retruded contact position prior to stable intercuspal closure, and the majority of both groups had a deflective anterior shift from centric relation to centric occlusion, mainly in a lateroprotrusive direction. The symptom group appeared to have a greater frequency of bilateral balancing side contacts compared with the control. A dominant canine disclusion tended to occur more frequently in the control group. While these results indicate that the temporomandibular joint dysfunction and control subjects have equally less-than-ideal occlusions, it may be that the border zone of accommodation of each subject is significantly different from the others.

Electromyographic investigations of the masticatory musculature in man with comparisons between groups of individuals with different types of occlusion have, as a rule, given negative results (Ingervall and Thilander 1974). This is not surprising because the morphology of the dentition may vary independently of skeletal morphology, so that individuals differing in type of occlusion may resemble each other in facial morphology. Ingervall and Thilander (1974) found that patients with considerable muscle activity are characterized by rectangular shape of the face in profile and small lower face height. Ahlgren (1970) established that Angle Class III malocclusions develop abnormal muscle contraction patterns during masticatory function, with a significant reduction in the average EMG potential, and that the abnormal muscle function is related to the characteristic jaw form of Angle Class III malocclusion. Carlson, Ingervall, Lewin and Molin (1976) found a significant correlation between greater facial height and occlusal disturbances (mainly occlusal interferences). Ingervall and Thilander (1974) demonstrated

a decreased masticatory muscle activity in long faces.

Mohlin and Kopp (1978) found that crossbite and anterior openbite were more common in a group of patients with mandibular dysfunction. Also, tipping of the teeth and bilateral crossbite seemed to be associated with mediotrusive interferences, while unilateral or bilateral crossbite seemed to be associated with interferences between the retruded and intercuspal mandibular positions. No correlation was found between any of the interferences or malocclusions and the severity of mandibular pain and dysfunction. This is in agreement with the findings of Ingerval and Thilander (1975).

Mohlin, Ingervall and Thilander (1980) believe that some malocclusions have a strong correlation to mandibular dysfunction and cuspal interferences. In their study Angle Class III malocclusion was associated with the severity of clinical symptoms, and mandibular overjet with faulty contact in retruded position (i.e. unilateral contact in retruded position and/or contact only between front teeth in retruded position) and faulty relation of retruded position to intercuspal position (i.e. lateral deviation between retruded position and intercuspal position and/or a distance between retruded position and intercuspal position of 2mm or more). Anterior openbite was the only variable which was strongly correlated to mediotrusive interferences. This is probably due to lack of anterior guidance. Mohlin, Ingervall and Thilander (1980) could not find any association between mandibular dysfunction and Angle Class II malocclusion and deep bite.

In an effort to determine what portion of an orthodontic practice consisted of patients with temporomandibular joint pain-dysfunction symptoms, Perry (1969) evaluated a group of 1146 patients, aged 10 to 23 years. It was found that 15.5% of the patients had temporomandibular joint symptoms. Three percent of these patients had one or more symptoms at the time of their first orthodontic examination. An additional 5.1% developed either transient

or continued symptoms during active therapy. Finally, 7.4% of the patients first noticed symptoms after treatment, during the retention period. Of the total series of patients with temporomandibular joint pain-dysfunction symptoms, 5.1% continued to have their problems even after retention was completed. However, more than half of this latter group had originally developed their symptoms before orthodontic therapy.

Williamson (1977) surveyed 304 patients, with a mean age of 12.9 years, to investigate the percentage of potential temporomandibular pain-dysfunction patients seen as adolescents prior to orthodontic treatment. Of the 304 subjects, 107 were symptomatic. Sixty-two had Class I malocclusions, 39 had Class II malocclusions, and 6 had Class III malocclusions. Nineteen had openbite and 58 had 50% or greater overbite. Williamson believes this investigation agreed with his clinical experience of adult dysfunctional patients. He says that there seems to be a strong predisposition for these patients to have high mandibular planes, and Class II Division 1 malocclusions with openbites anteriorly, or, on the contrary, deepbite with a flat mandibular plane angle and Class II Division 2 malocclusions, or Class I deepbite malocclusions with excessive anterior guidance. Williamson (1981) says that the main indications of incipient dysfunction are joint noises and pain on palpation in the muscles of mastication. In adolescents, he says, clicking will be observed much more often than crepitus or grating. Williamson (1977) states that the most significant point to be learned from his survey is the need for a thorough diagnosis, and an awareness by the orthodontist of potential temporo-mandibular joint dysfunction prior to the initiation of treatment. These patients need thoughtful care during treatment, and precise finishing.

5.4 OCCLUSAL CONSIDERATIONS IN BRUXISM

Bruxism is the most common parafunction (Dubner, Sessle and Storey 1978). The term "bruxism" is derived from the French "la bruxomanie", suggested by Marie and Pielkiewicz in 1907 (Ramfjord and Ash 1971). It includes both nonfunctional grinding and gnashing (eccentric bruxism) as well as clenching of the teeth in intercuspal position (centric bruxism). The incidence of bruxism is difficult to determine, since the criteria used in diagnosing it vary (Dubner et al 1978). Estimates vary from about 15% based on subject awareness, to 85% based on occlusal signs (faceting).

The symptoms most commonly associated with bruxism are those resulting from hyperactivity in the masticatory muscles (Dubner et al 1978). Here the symptomatology and its underlying cause are common with that of the temporomandibular joint pain-dysfunction syndrome. Patients may complain of tense, tired, levator muscles, or headache, or pain referred to other areas such as the temporomandibular joints. Muscle pain may also be reported in the neck and lower back muscles, suggesting a generalized muscular hyperactivity.

Klineberg (1980c) says that parafunction or jaw clenching and tooth grinding is a manifestation of daytime stress and anxiety, and it is not evoked by tooth contact interferences. Beyron (1969) claims that bruxism may occur as a result of severe psychic tension and a minor occlusal interference, or marked occlusal interference and mild psychic tension, the average tolerance levels being between these extremes. Dawson (1974) maintains that if muscle tension is increased by stress, the tendency to grind the teeth is also increased, but only if interferences are present. Egermark-Eriksson, Carlsson and Ingervall (1979) indicated that there was an increase in bruxism with age in patients with dual bite. Marks (1980) writes that sensitization must be considered as an aetiologic factor in some bruxism cases. Intermittent allergic oedema of

the Eustachian tube causes changes to occur in the tympanic cavity, reflexly initiating bruxism as a means of obtaining a patent Eustachian tube. Ramfjord and Ash (1971) believe that the muscle tonus can be increased by emotional or nervous tension, by pain and discomfort, and by occlusal interferences. An interplay of these three mechanisms provides the neuromuscular basis for bruxism.

The postural tonus contractions within the masticatory muscles are dependent upon the myotatic reflex activity, to which is added the gamma efferent or fusimotor activity (Ramfjord and Ash 1971). The myotatic reflex centre is closely related to the control of the conditioned reflex patterns of jaw movements, which have been developed as a result of nervous impulses from the various proprioceptors and sensory nerve endings in the masticatory system. The influence of the central nervous system on muscle tonus is mainly through the fusimotor system. A state of hypertonicity of the masticatory muscles might, therefore, be due to either central nervous system influence through the fusimotor system or local disharmony between the functional parts of the masticatory system acting upon the reflex mechanism which controls subconscious jaw movements. Failure of the protective reflexes to protect the dentition, muscles and joints could be attributed to a powerful inhibition of afferent input, or alteration in the behaviour, as a result of limbic brain influences on motor centres (Dubner et al 1978). Brain damage, such as cerebral palsy, drugs, such as amphetamines and dopamine precursors, and certain sleep states, such as light sleep, can predispose to bruxism.

Bruxism is probably the main cause of traumatic injury to the periodontium (Dawson 1974). It is the prime factor involved with most hypermobility, and is undoubtedly the major cause of excessive, premature wear. It is associated with temporomandibular joint pain, muscle spasm, split teeth and fractured fillings. Guichet (1979) agrees with this. On the other hand, Winter and Yavelow (1975) warn that the diagnosis of bruxism does not necessitate a

diagnosis of traumatic occlusion, pathosis, or temporo-mandibular joint pain-dysfunction syndrome, because of individual neuromuscular adaptation.

The signs of bruxism are attrition of the teeth, the so-called bruxo-facets, and changes in the supporting structures of the teeth (Dubner et al 1978). The wear patterns associated with bruxism are different from those associated with mastication and swallowing. Parafunctional facets are often outside the usual functional range of jaw movement, are flat, and are highly polished. The occlusal forces in bruxism are usually greater than functional forces and act over periods of time. If the response of the periodontium to increased forces through time is inadequate, the teeth may show increased mobility. In most individuals with fairly normal periodontal support, the common sequelae of bruxism, according to Ramfjord and Ash (1971), are compensating hypertrophy of the periodontal structures, thickening of the alveolar bone, increased trabeculation of the alveolar process, wider than normal periodontal membrane, made up of heavy collagenous fibres, and a well-developed fibre attachment to the cementum.

5.5 OCCLUSAL CONSIDERATIONS IN OCCLUSAL TRAUMA

Occlusal function, and its relation to periodontal disease, has been debated since Karolyi in 1901 first suggested such an interaction (Stahl 1970). Occlusal trauma has been defined as that force, or forces, caused by mandibular movement and resultant tooth percussion, capable of producing pathologic changes in the periodontium. Occlusal traumatism is the term applied to the tissue changes which occur as the result of this trauma. These tissue changes are limited primarily to the attachment apparatus and are non-inflammatory in character. At the site of pressure, they essentially consist of:

A. Resorption of bone and sometimes cementum
B. Necrosis of bone and sometimes fibres
C. Haemorrhage
D. Thrombosis of vessels.

At the site of tension, they essentially consist of:

A. Apposition of bone and sometimes cementum
B. Alterations and elongation of the periodontal fibre apparatus.

Radiographic examination will depict the periodontal membrane thickening to a maximum at the gingival level (Graham 1968). As a result of this thickening the tooth will have some mobility, and this is also readily identifiable by tapping the teeth from the labial or buccal, when the tooth with the thickened membrane will have a decreased resonance.

Lewin and Lemmer (1974) believe that prevention of the development of zones of persistent localized stress concentration should be a worthy objective of orthodontic treatment.

Stahl (1975) states that both human and experimental data negate any causal relation between occlusal traumatism and the initiation of inflammation of the gingival margin. On the other hand, excessive occlusal forces have been consistently shown to affect the

periodontal tissues apical to the crest of the alveolar bone by creating sites of compression and tension. Glickman (1971) says that, just as the occlusion is a critical environmental factor in the life of the healthy periodontium, its influence continues in periodontal disease. Occlusion, he says, is a factor in periodontal disease: it may be favourable or unfavourable. If occlusion is favourable, inflammation is the sole destructive factor in periodontitis. If occlusion is unfavourable, it alters the environment, and the pathway of the inflammation produces periodontal injury, and becomes a co-destructive factor that effects the pattern and severity of tissue destruction in periodontal disease.

Kloehn and Pfeifer (1974), in a study of fifty treated orthodontic patients, found that orthodontic treatment did not cause any irreversible periodontal destruction. Inflammatory and hyperplastic changes in the gingiva, which occurred during treatment, were reversible upon appliance removal, and the periodontium was in better health following treatment. There was a direct relationship between oral hygiene and periodontal disease.

Thus, most investigators feel that occlusal trauma is not the initiator of chronic periodontal disease, but a catalyst (Chiappone 1975). Either way, as a principal factor or as a catalyst, it is a factor, and we must deal with it in our understanding of orthodontic finishing.

CHAPTER 6

Application of Occlusal Concepts To Orthodontic Therapy

6.1 ORTHODONTIC THERAPY LIMITATIONS

Andrews (1976) presented the results obtained from a study of 1150 cases treated by prominent American orthodontists. He does not say whether or not these cases were out of retention, or just after the removal of bands. There were indeed significant differences between "nature's best" and "orthodontia's best".

Key I: 80% of treated cases had molar relationships or posterior occlusion that differed from that of the non-orthodontic "normal" occlusions.

Key II: In 91% of the treated cases crowns had obviously improper mesiodistal tip, resulting in faulty contacts or posterior occlusion or spaces. The upper laterals, canines and second molars were most frequently undertipped.

Key III: 78% of treated cases had insufficient anterior crown inclination resulting in improper posterior occlusion or spaces or anterior overbite. Often the upper posterior crowns were also insufficiently inclined.

Key IV: Obvious rotations in 67% of the treated cases interfered with the opportunity to attain "normal" occlusion. Upper molars and teeth adjacent to extraction sites were most frequently in error.

Key V: Unnecessary spaces were evident in 43% of the completed cases. Extraction site spaces due to insufficient closure, and spaces due to insufficient anterior crown inclination, were the most common errors.

Key VI: Excessive curves of Spee in 56% of treated cases eliminated any possibility for "normal" occlusion to occur.

Berg (1979) evaluated 264 consecutively treated cases by the light-wire edgewise technique, and found that his defined treatment objectives were only achieved in 43% of the cases. This is even more suprising when consideration is given to the fact that not all of Andrews' Six Keys were considered, nor were functional or gnathological concepts included among the criteria.

Hellman (1921) stated that "perfect" occlusion, as conceived by the orthodontists, is mythical. Despite limitations, good orthodontic treatment yields good results, but we do not get or expect perfection (Barrer 1974). These limitations, no matter where they occur in the sequence of correction, are conceived in diagnosis, born in case planning, grow in treatment, and mature in retention. They never die; they haunt us post-retention.

Orthodontic treatment is a qualitative and/or quantitative morphological change, and success or failure will depend on whether the change is within the "permissible range" of adaptation (Timms 1964). Every individual represents some form of compromise in his or her make-up. The very fact that a patient presents with a malocclusion is a basic indication that we have a deviation from the "ideal norm" in which some adaptation has already occurred (King 1974).

We must learn to think in terms of an achievable optimum, rather than at times abusing the anatomy and physiology of the patient in pursuing the figmentary "ideal normal" (King 1974). In many patients secondary factors such as inharmonious or disproportionate skeletal parts, inadequate muscle structure, psychologic factors causing prolonged habits, discrepancies in tooth size or tooth form may alter absolute ideal objectives (Ricketts 1978). Generalization fails completely when applied to the individual (Goldstein 1965). The individual is, and will forever remain, a unique biologic mechanism, in which variation is the rule.

Schudy (1974) says that posttreatment craniofacial growth will, in large measure, determine the final pattern of dental and associated skeletal relationships, and the function thereof. Consequently, this growth can have far-reaching effects on the dentition of the person who has completed orthodontic treatment in terms of alignment of the lower anterior teeth, overbite maintenance, and temporomandibular joint - occlusal harmony.

Several workers have noted the progressive uprighting of the incisor teeth as the jaws grow to maturity (Schudy 1974). Schudy says that this uprighting seems to be primarily a result of the functional forces that exist in the incisor area as the mandible grows forward. Siatkowski (1974) claims that a late growth change, the lingual uprighting of incisors via pure tipping, can fully account for decreases in anterior arch circumference. Schudy (1974) says that just how the incisors will compensate as jaw growth terminates not only determines the future interincisal angle, but is a function of the size of this angle when treatment is completed. According to Schudy, an ideal positioning of the upper and lower incisors is an edge-to-edge bite which would tend to place the functional forces near the incisal edges and minimize the tendency of these teeth to upright with further mandibular growth.

If the mandible and the maxilla grew forward equally after treatment, no particular effect on the interdigitation of the teeth would be expected (Schudy 1974). However, it has been shown that the mandible usually grows forward more than the maxilla. Bjork (1963) found that growth of the condyles can be detected in some persons even after the age of 20 years, and can be vertical, sagittal or any direction in between. Schudy (1974) believes that this greater increase in prognathism of the lower jaw is responsible for a "socking in" effect causing a better Class I molar and premolar relationship, and a mesial axial tipping of the upper first molars. If, however, after treatment, anterior vertical facial growth prevails over condylar growth and the mandible is forced down and back, it is probable that a slippage of a good Class I relation could occur and worsen buccal interdigitation.

Thompson (1961) warns that while incremental and directional growth of the facial parts can be our ally in treatment, continued growth subsequent to treatment can be our functional foe. A spurt of facial growth after the attainment of an "ideal" anatomical occlusion, may result in trauma to the

supporting tissues and the temporomandibular joints (Thompson 1972). Function of the various parts of the stomatognathic system must be examined before, during and for some years following mechanical therapy. Treatment that is completed too soon because it was started too early, may produce a dentition that is only temporarily harmonious with the joints and muscles, and future disproportionate growth may introduce such unharmonious conditions as incisal interference, posterior mandibular displacement, or premature contact of teeth (Thompson 1962).

Histological work by Reitan (1959) has demonstrated that the orthodontic rotation of teeth is accompanied by a displacement and apparent stretching of the fibres of the periodontal ligament. While the tooth is retained in its new position, rearrangement of these fibres gradually takes place (Pinson and Strahan 1973). The displacement of the gingival group of fibres, however, persists for very much longer than that of the principal periodontal fibres. Pinson and Strahan (1973) found that the rotational relapse which occurs after the gingival fibres have been severed, is significantly less than in a comparison group without surgical intervention. Pinson and Strahan (1973), Rinaldi (1979) and Boese (1980a) say that there is no significant increase in pocket depth, gingival recession, or loss of alveolar crestal bone subsequent to pericision. Boese (1980a) warns that the principal periodontal fibres, which are not affected by surgery, can also contibute to the relapse force if not stabilized for long enough.

Begg and Kesling (1977) say that proximal trimming of the upper and lower anterior teeth play a valuable role in preventing relapse after orthodontic treatment, as well as a means of reducing the lengths of the dental arches. Boese (1980a) agrees with this. It can also be used to adjust a Bolton's discrepancy, where the amount of tooth structure in one arch is excessive relative to the other arch. Boese (1980a) warns that a positive correlation exists between an increase in anterior overbite and increased lower incisor

stripping. Boese also says that stability has always been a key objective in orthodontic treatment since, without stability, both "ideal function" and/or "ideal aesthetics" may be lost. Circumferential supracrestal fiberotomy, reproximation and adequate retention procedures may aid in the achievement of these objectives.

Controversy arises as to the ability to achieve a functional occlusal orthodontic result, based on gnathological concerns. Tuverson (1980) says that an orthodontic treatment objective, if not the orthodontic treatment objective, would be to produce an orthodontic result where centric relation and centric occlusion coincide, where, in centric relation, all opposing teeth would contact their antagonists simultaneously with the absence of any mandibular slide, and where, in eccentric excursions, the anterior teeth, especially the canines, would disarticulate the posterior teeth after a slight movement. This "ideal" relationship is seldom attained. However, some orthodontists believe that the closer this relationship is approached, the more stable will be the orthodontic result, and the less the possible risk of future occlusal trauma and temporomandibular joint disturbances. Aubrey (1978) believes that when the orthodontist uses centric occlusion as the starting point for diagnosis and treatment procedures, he may be asking the condyles to make an adaptation that cannot be tolerated indefinitely. Barnett (1978), Roth (1976, 1981), McHorris (1979), Chiappone (1975) and others believe that non-attritional, functional occlusion as defined in Chapter 3, is an attainable orthodontic goal.

Roth (1981c) says that the teeth can be set up so that they do not interfere with the envelope of mandibular movement. This type of occlusion, he says, requires little adaptation on the part of the patient and, as such, it is the least likely arrangement to produce untoward symptoms. Roth states, however, that less than 1% of completed orthodontic cases actually have a coincidental "true centric relation" and centric occlusion. A realistic objective, he believes, is to treat the orthodontic case close enough to centric relation that there is not a discernable discrepancy between centric

relation and centric occlusion; close enough that, if equilibration is ever necessary, the case can be equilibrated to a result that provides proper anterior coupling and guidance, and enough centric stops to hold centric stable.

Timm, Herremanns and Ash (1976) maintain that the rigid philosophical goals of gnathology are seldom realistic orthodontic goals. The myriad of cusp shapes, jaw forms, facial patterns, ranges of muscle contractions, condyle-fossae contours, and tooth contact times and range, indicates that a single concept is too stringent and mechanistic to fit all of the patients (Perry 1976). It is naive presumption to expect to achieve with orthodontic appliances, the same precise relationships that would be achieved in a lifetime by the natural dentition (Thurow 1977). The level of precision attainable with an orthodontic appliance is not adequate for such detailed positioning. Moreover, tooth mobility and posttreatment functional adjustments so far exceed the dimensions involved in occlusal adjustments, that the results of such an effort would be little more than a fleeting change.

The limitations of these concepts of occlusion do not mean that an "acceptable" functional occlusion cannot be attained in the vast majority of orthodontic cases (Timm et al 1976). Orthodontic goals do require careful positioning for "functional adaptation" (Thurow 1977). The objective is to avoid interferences that might prevent the teeth from settling into a "good" functional relationship, and then incorporate guidance and support for that adaptation into finishing and retaining procedures. Williamson (1981) says that the ultimate objective is to preserve the dentition and jaws in a healthy state for the rest of the patient's lifetime, with the least amount of treatment. In summary, if the orthodontist strives for an idealized functional result, with clear-cut functional requirements in mind, his percentage of functional problems should be reduced. How this functional concept can be related in terms of "form" is not yet clear, and is the subject of Part II of this study.

6.2 ARTICULATORS

The most important single purpose of an articulator is to relate the upper and lower models to the correct horizontal axis (Dawson 1974). Simple hinge articulators do not permit a correct relationship to the axis of closure. Anteroposterior differences in the location of the maxillary cast also cause very different paths in lateral excursions (Hohl 1978b).

Today the market is flooded with articulators, both fully adjustable and semi-adjustable to enable casts to be connected. Which to use, and why, is a problem (Wood 1977). Wood says that to get the general practitioner, or even the specialist, to use a semi-adjustable articulator would be a wonderful advancement.

Hohl (1978b) provides a classification of articulators, from which he chooses a semi-adjustable type, adjustable to the opening and closing movement, the protrusive and right and left jaw positions or movements, for planning segmental surgery. He says that the instruments that reproduce pantograms, graphic tracings and timing of Bennett movement, are too time consuming and employ needless accuracy, which cannot be duplicated in the surgical procedure (or orthodontic therapy). On the other hand, Chiappone (1975) preferred to use a fully adjustable articulator. Since then he suggests using the Denar mini-recorder instead of the pantograph (Chiappone 1977, 1980). Chiappone claims that this information is extremely important in determining the crown inclination of the upper central, lateral and canine complex; whether or not the case will have canine protection or canine interference; the crown inclination of the lower canine, and the angulation of the lower central and lateral incisors.

The biggest shortcoming of semi-adjustable articulators is that condylar pathways are limited to straight lines (Dawson 1974). Because of this limitation, these instruments are referred to as check-bite articulators. This means that

the horizontal condylar paths are set to align with a bite record made at centric relation, and another bite record made in the protrusive position. The resultant path is a straight line between the two points. Lateral pathways are set from the centric bite record plus bite records made in the left lateral and right lateral jaw positions. The resultant straight line gradual side shift of the balancing condyle determines the amount of immediate side shift for the working side condyle. If pathways in the skull curve between the two check bite positions, the curve will not be duplicated on the articulator.

Thurow (1977) cautions that technical refinement of techniques and instrumentation in articulators have reached a level of precision that far exceeds the accuracy that can ever be achieved at the vital patient-instrument interface. He provides the following limitations of the articulator:

A. The most serious limitations on articulator studies are the complexity and resiliency of the joint and its movements. There is no way that a hard, round ball can provide any more than a rough approximation of the flattened ovoid cylinder that forms the head of the condyle.

B. Plaster casts do not reproduce the natural mobility of the individual teeth that is provided by the periodontal membrane.

C. From the orthodontic veiwpoint, the most serious limitation of articular studies is the fact that serial analysis is extremely difficult and rarely undertaken. The articulator reproduces the rapid movement of function as they relate to the bony articulations, but the dynamic nature of the dental articulation with its ongoing changes throughout life is lost.

6.3 DIAGNOSIS AND TREATMENT PLANNING

6.31 Functional versus structural diagnosis

In most patients the dentition represents a structural problem, and the static analysis of the plaster casts permits interpretation with the patient's other records (Perry 1969b). However, the orthodontist must not jump to the conclusion that form and function are always coincidental (Roth 1976). As valuable as the anatomic guidelines and parameters may be in diagnosis and treatment planning, the orthodontist is still frequently in need of other means to assess the function of the occlusions he treats, both prior to, during and after treatment.

A diagnosis based upon gnathologically articulated models is an aid to put alongside other orthodontic diagnostic records (Cottingham 1978). With a gnathological diagnosis, the orthodontist can see and measure how far he must move each tooth. He may see what would appear as a Class III relationship change to a Class I, or even to a Class II condition. An accepted Class I occlusion, from a casual observation, may change into a traumatic Class II malocclusion. What appears to be a unilateral cross-bite will often change to be a bilateral distal occlusion. Most patients, according to Cottingham, will show a deflection that hides the severity of distocclusion.

Occlusal disharmony is a purely functional concept and can occur in any morphologic malocclusion (Ingervall 1976). Ingervall maintains, however, that rarely is comprehensive analysis using an articulator necessary. In most patients simple clinical examination is enough. Aubrey (1978), Mathews (1967) and Perry (1969) agree with this in most cases.

On the other hand, Baltas and Tsellos (1964) say that the mouth cannot be used as a functional articulator. The neuromuscular positioning of the mandible to compensate for occlusal discrepancies will, many times, hide the true

discrepancies (Roth 1981a). On the articulator the orthodontist can measure the difference in overjet between the habitual centric closure and hinge-axis closure on equilibrated models, and divide the discrepancy into its vertical and horizontal components. Roth also says that the cephalometric roentgenogram can be adjusted according to these measurements. Heide and Thorpe (1965) cautioned about the possible discrepancy between centric occlusion and centric relation in cephalometric roentgenograms. Wood (1977) also suggests a method for obtaining centrically-related cephalometric roentgenograms.

Van Beek et al (1976) state that articulator-mounted models are especially helpful in:

A. Cases with apical base discrepancy
B. Cases with pronounced tooth-size discrepancy
C. Cases with a well-developed neuromuscular avoidance pattern.

Tuverson (1980) maintains that a diagnostic setup on articulated models can be of great benefit in cases with interocclusal arch length deficiency cases. It may be desirable to first carry out a Bolton's analysis to determine the indication for the set-up.

The study casts in adult orthodontics, surgical orthodontics, and certain functional problems, should be articulator-mounted (Perry 1969b). Williamson (1976) and Parker (1978) also state that the articulated models may serve as a means of communication between specialties, and between the orthodontist and the general practitioner.

6.32 Orthognathic surgery

Worms, Speidel, Bevis and Waite (1980) stress that, while surgery has broadened the treatment horizons for the surgeon and orthodontist, it has also introduced iatrogenic sequelae requiring sophisticated and complex orthodontic measures. Communication between the orthodontist and the oral surgeon is an absolute necessity. They must assume a

common treatment goal, not only aesthetically, but functionally as well (Roth and Ware 1980).

Hohl (1978a) says that centric relation is the only reproducible position when centric occlusion is being altered by orthodontic tooth movement or orthognathic surgery. Centric relation allows an accurate prediction of surgical movement needed and may eliminate distraction of the condyles during intermaxillary fixation. Gnathological concepts are extremely important whenever vertical dimension is altered (Worms et al 1980). Alteration of the vertical dimension directly affects centric relation and centric occlusion. A hinge-axis transfer and a semi-adjustable articulator must be used when constructing surgical splints and positioners, or when performing occlusal equilibrations or model surgery. Failure to utilize an accurate hinge-axis transfer may automatically build relapse into orthodontic posttreatment stability and most assuredly into post-orthognathic surgery, with ensuing open or closed bites.

Hohl (1978b) presents a method for model surgery, preoperative cephalometric prediction tracing, and splint construction which endeavours to achieve the functional and aesthetic goals necessary in orthognathic surgery.

6.33 Adult orthodontic therapy

Mohlin and Kopp (1978) claim that the need for treatment in the adult population is probably not less than for children, owing to a more limited orthodontic service earlier and because secondary malocclusions may have been created by loss of teeth. The adult, unlike the child, is a relentless patient who will not cover deficiencies in the skills of diagnosis, or errors in the use of mechanical procedures by helpful settling in treatment or posttreatment. It is easy to sow the seeds of oral destruction if the orthodontist ignores the principles of adult histology and physiology, the interrelation of joint, occlusion and muscles, and the requirements of proper diagnosis, mechanics

and retention (Barrer 1977). The basic aim should be to harmonize the dentition with the temporomandibular joint and supporting musculature (Mathews 1967).

For the adult, the clinical examination takes on special significance in isolating existing or potential pathosis and the aetiologic factors of trauma (Barrer 1977). Adult orthodontics is often symptom related, whereas with the child, the orthodontist is largely dealing with signs (Ackerman 1978). Adult dentitions are more likely to be periodontally involved, with a quantitative reduction in the amount of supporting tissue. Gazit and Lieberman (1980) emphasize the need for a multidisciplinary approach to treatment. Communication between the periodontist, restorative dentist and orthodontist, must include an assessment of the functional occlusion.

6.34 Orthodontic therapy for the patient with temporomandibular joint dysfunction

When examining a new patient, the orthodontist should be alert to the possibility that a temporomandibular joint syndrome is lying dormant (Parker 1978). Orthodontics is an important facet of the therapeutic possibilities for the patient with a well-developed functional disorder (Thurow 1977). Some of these cases have progressed so far that repositioning of the teeth offers the only hope for achieving a reasonably normal relationship. When the discrepancies are so severe, orthodontics can provide a starting point for further adjustment and restoration. Ingervall (1978) discusses orthodontic treatment for some adults with temporomandibular dysfunction symptoms and anterior crossbite, arch width discrepancies, buccal crossbite and tipped molars.

In developing a treatment plan for any particular temporomandibular joint dysfunction patient, it must be borne in mind that the occlusal result must be accomplished with unerring accuracy to a very high degree of precision, since the patient may primarily be seeking treatment for a

functional occlusion correction (Roth and Ware 1980).

Roth (1981a), Klineberg (1980c), Graber (1979) and Williamson (1976) suggest the prior use of a repositioning splint for patients with signs or symptoms such as:

A. Occlusal wear
B. Excessive tooth mobility
C. Temporomandibular joint sounds
D. Limitation of opening or movement
E. Myofacial pain
F. Contracture of mandibular musculature making manipulation difficult or impossible
G. Some types of tongue-thrust swallow.

Klineberg (1980c) uses a maxillary heat-processed acrylic resin splint with flat plane contact against opposing teeth. The philosophy of occlusal splint therapy is based on three requirements:

A. To remove guiding influences of cuspal inclines from the terminal phase of cyclical jaw movements
B. To provide a stable surface for simultaneous contact of opposing teeth at the point of maximal contact following each cyclical jaw movement
C. To ensure multidirectional freedom for jaw movements to occur from median occlusal position to terminal hinge position, and freedom to execute smooth eccentric jaw movements.

Besides achieving muscle relaxation and eradication of neuromuscular reflexes, the splint acts as a differential diagnostic tool (Williamson 1976). Roth (1981b) says that the repositioning splint is a removable "mutually protected" occlusal scheme, that can be used to test the patient's response to a change in the occlusion without really doing something that is not reversible. If the occlusal interferences are not the cause of the patient's problem, the splint can be discarded (McNeill et al 1980).

Roth (1981b) continues splint therapy until there has

been no change in mandibular positioning in centric relation for at least three months. He says that the mandibular postural changes during splint therapy are of three different types:

A. Changes due to relaxation of the musculature that postures the mandible incorrectly;

B. Changes due to elimination of intracapsular inflammatory fluid;

C. Changes due to remodeling or recontouring of the bony parts of the joints.

Beard and Clayton (1980) found that occlusal splint therapy reduced the temporomandibular joint dysfunction muscle symptoms of incoordination to coordinated function. All patients, however, had a return of pre-treatment temporomandibular joint dysfunction muscle symptoms following removal of the occlusal splint. Patients with initially higher temporomandibular dysfunction scores required a longer period of occlusal splint therapy to become free of dysfunction. Patients with a longer history of temporomandibular joint dysfunction recquired a longer period of occlusal therapy to become free of the symptoms. The use of occlusal splint therapy alone to treat the muscles, they conclude, is not enough to maintain muscle coordination.

6.4 OCCLUSAL CONSIDERATIONS IN ORTHODONTIC FINISHING

6.41 Finishing with the Begg Technique

According to Begg and Kesling (1977), overmovement of teeth plays a decisive role in bringing about higher standards of finished results of treatment. As a result, overmovement features prominently in the finishing phase of their treatment. Although the control exerted by springs, auxiliaries, elastics, elastic thread, and heavier archwires in Stage III does not provide the same precision as, for example, that between bracket and archwire in the edgewise mechanism, this need not pose a disadvantage in precise tooth positioning (Swain

1975). On the contrary, the pivotal relationship can still be put to good advantage, and this is done through the use of overcorrection. Begg and Kesling (1977) believe that the proper time to remove the tooth-moving appliances is not when all the teeth are in the positions in which it is wished for them to remain as the finished product of treatment, but rather when all teeth have been moved beyond the positions they are finally intended to occupy.

Precision is in the hands of the orthodontist; it is not inherent in his appliance (Perry 1969). According to Wasson (1979), if a thorough examination and dignosis has been performed to determine the existing conditions, and if the orthodontist has a good mental image of where the teeth should be at the end of treatment, then he can usually accomplish his "goals" with whichever appliance he feels most comfortable. The appliance itself is not as important as the orthodontist's ability to use it.

Usually the end results that all techniques strive for are the same, only the priorities and methods for achieving them differ. For example, in the Begg technique, Begg uses overcorrection, an upper circumferential retainer, and depends on "settling" to a large degree, whereas the Kesling and Rocke group use a tooth positioner to guide the teeth from overcorrected positions into "normal" alignment, inclination and occlusion (Rocke, Kesling. Rocke, Rocke and Barrer 1980). Swain (1975) also uses a Stage IV phase of treatment.

Thus, finishing provides the most controversial aspect of Begg therapy, and at the present time is producing the main area of criticism aimed at orthodontists using the technique, by other orthodontists, by gnathologists and by general practitioners. In an era where occlusal aspects are becoming more and more emphasized, Begg operators will have to look closely at, and follow-up closely, their finished products no matter what method of finishing they use, be it Stage IV mechanics, with round or rectangular wires, tooth positioners or overcorrection and "settling".

Thompson (1981) says that the most difficult part of Begg treatment is the finishing period, because control of buccolingual torque on posterior teeth is difficult. He suggests the use of a combination bracket design,* in which the lower third of the bracket is a Type 256 Begg bracket, and the upper two thirds of the bracket is a 0.018 by 0.025 inch straight wire slot with in-and-out positioning, preangulated and pretorqued. He uses the light, rapid tipping forces of Begg to correct gross changes in tooth position early in treatment, and the bodily movement principles of the straight wire type of appliance later in treatment to produce maximum tooth detailing and occlusal intercuspation. He says that optimum occlusal settling is possible only if the teeth are in their best three-dimensional position and in best relation to the functional paths. These are established most accurately, he says, with proper torque, uprighting, and arch form.

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6.42 Overcorrection

Begg and Kesling (1977) emphasize the following overcorrections in finishing:

A. Upper and lower incisors that are too protrusive before treatment, in Class I and Class II malocclusions, should have their roots overmoved lingually.

B. In Class II Division 2 malocclusions, the roots of the upper anterior teeth should be overmoved lingually.

C. When the four first premolars are extracted, the roots of canines should be overmoved distally.

D. In nonextraction cases the roots of canines should usually be overmoved distally.

E. All rotated teeth should be overrotated.

F. Posterior teeth should be overmoved to overcorrect whatever form of malocclusion was originally present.

G. In some Class III cases it is necessary to incline the crowns of the upper anterior teeth too far labially and the crowns of the lower anterior teeth too far lingually in order to mask a Class III relationship.

H. Deep anterior overbites should be overcorrected to the extent of sometimes producing an anterior openbite.

I. Where there is originally an anterior openbite, the teeth should be overmoved to produce an excessive anterior overbite.

Swain (1975) refers to overcorrection of rotations, overbite, openbite, antero-posterior relationships (Class II and Class III), angulations and inclinations.

Roth (1981c) says that overcorrection must be built into certain areas of the appliance, to create tooth positions that will tend to settle in the most favourable manner because:

A. Teeth will move after appliance removal, no matter where they are placed.

B. The curve of Spee will return or deepen after appliance removal.

C. Teeth that are slightly tipped distally in the buccal segments, will tend to settle better than teeth that are

already mesially inclined.
D. As teeth in the buccal segments settle, they will tip mesially and rotate mesially.
E. As band spaces close, there is a corresponding decreasing crown inclination of the anterior teeth.
F. Teeth adjacent to an extraction site will tend to rotate towards the extraction site.
G. Teeth adjacent to the extraction sites will tend to tip towards the extraction site.
H. Maxillary lingual cusps will tend to migrate downward until they find an occlusal stop against the opposing teeth.

Roth (1981c) believes that Andrew's Six Keys are the most ideal functional and aesthetic arrangement of the teeth after appliance therapy has been discontinued and the occlusion has settled.

It is obvious that, as far as the need for overcorrection is concerned, little controversy arises. However, when and how the teeth should move back into good static and functional occlusion provides the point of question.

According to Watson (1980), we want to build some ideal or physical stress-resistant qualities into our optimal occlusion, because many finished occlusions "settle out" rather than "settle in". Assumptions that "settling in" will solve functional deflections should not be made (Williamson 1976).

6.43 Functional occlusion considerations in finishing procedures

Most authors agree that the occlusion should be checked thoroughly, both statically and functionally, prior to band removal. Cottingham (1969), Roth (1976), Chiappone (1975), Barnett (1978) and others suggest assessment on "centriculated" posttreatment casts. This may be incorporated into the technique for positioner construction. Some authors (Roth 1976), (Barnett 1978) suggest removing active auxiliaries and archwires, and allowing a period of settling prior to assessment.

A. Centric relation

Perry (1969) stresses the need to check the maxillary-mandibular relation prior to removal of appliances. We must master the art of mandibular manipulation, removing the initiative of closing from the patient, and thereby eliminating the feedback mechanism from closing patterns that deviate the mandible away from the premature contact (Chiappone 1975). This cannot be dismissed as irrelevant only because of the many theories of what and where centric relation is. This may not be the final jaw relationship that is established, but does permit elimination of mandibular postural changes often present after long-term elastic therapy (Perry 1969).

Wasson (1979) suggests some of the causes of centric slide:
a. Lack of coordination in the widths of the dental arches. This is very common in patients with Class II malocclusions who have a short, narrow mandible. The mandible is forced forward to intercuspate with the wider maxilla. In treatment, the maxillary arch must be constricted and the mandibular arch must be expanded slightly to allow proper centric relation closure.
b. An extruded tooth due to improper bracket placement or unsupported elastic wear. If the cause is improper bracket placement, either a change in the band position, or an offset in the archwire, will correct the problem. If extrusion is due to the forces exerted from the interarch elastics, discontinuation of the elastics may solve the problem, provided the tooth is cut free from the archwire and given a chance to settle back into place.
c. Extruded cusp due to improper torque. The buccolingual inclination of the posterior teeth must be correct to have proper cuspal relationships. The A,B and C interocclusal contacts are directly affected by the buccolingual angulations which, in turn, are controlled by the crown torque placed in the archwires. The most common aspect of the problem is a lack of sufficient lingual crown torque in the maxillary molars, which makes the lingual cusp hang down too far, creating centric or lateral interferences. The next most common error is too much lingual crown torque on the lower

molars, which makes them roll into the lingual area and create interferences of their buccal cusps. These tendencies are quite strong and must be counteracted throughout treatment with active torque force in the archwires. Techniques using only round wire may lack the necessary control in this area of treatment. A good way to check posterior torque is to sight along the buccal surfaces of the posterior teeth as viewed from the front of the mouth. All the maxillary teeth should appear at the same inclination from the canine posteriorly. The mandibular teeth, however, will have a progressive increase in lingual crown torque from the canine through to the second molar.

d. Improper angulation in a mesiodistal direction (tip) may cause cuspal interferences. All teeth should have the roots angled slightly in a distal direction, with the long axis of the teeth roughly parallel to each other. Teeth that are not upright may cause interferences, because the occlusal surfaces may be at the wrong angle to properly occlude with their antagonists. The problem can be more easily controlled with proper bracket angulation than is the case with torque positions. Therefore, fewer problems are found with mesiodistal angulation than with torque in edgewise-treated cases. Whether this is the case in Begg-treated cases is investigated in Part II of this study.

e. Rotation of posterior teeth will cause the malpositioned cusps to offer centric interferences. Lateral interferences will likely occur also because of incorrect ridge and groove direction. All the teeth in the arch should form a continuous line along the labial and buccal cutting edges.

f. Posterior position of the mandibular arch due to a short mandible will also cause a centric slide This is a most difficult condition to correct in a short time because basically it is a skeletal problem.

g. Anterior position of the maxillary arch due to loss of anchorage, resulting from poor patient cooperation, can be one of the most frustrating causes of centric slide.

h. Correction of a unilateral Class II molar relationship will often cause a midmost discrepancy. These problems are particularly difficult to correct if there is also mandibular asymmetry.