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A Comparative Study of Two Techniques Used for Determining the Seated Condylar Position in Human Subjects

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A COMPARATIVE STUDY OF TWO TECHNIQUES USED FOR DETERMINING THE SEATED CONDYLAR POSITION IN HUMAN SUBJECTS

by

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VITA

Gary Todd Klein was born in Chicago, Illinois on March 13, 1959.

He began his predental education in 1977, at the University of Michigan, Ann Arbor, Michigan, where he received a Bachelor of Science degree with honors. In 1981, he entered Loyola University's School of Dentistry in Maywood, Illinois. He graduated in 1985 as Valedictorian of his class.

Upon completing his general dental education, Dr. Klein began his graduate studies in the department of Oral Biology and postgraduate studies in the Orthodontics department at Loyola University School of Dentistry. These studies eventually led to a Master of Science degree in Oral Biology and a Postgraduate Certificate in Orthodontics.

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CHAPTER I

Introduction

The concept of centric relation has been used in dentistry for many years. There have been many schools of thought concerning occlusion and each have had its own definition for the term, centric relation position. This term has been used in combination with other words such as, centric occlusion, centric relation, centric position, retruded centric relation, terminal centric occlusion, and unstrained centric relation. There has remained a general lack of agreement regarding the condyle-disc-fossa relationship and how it was described.

These terms and concepts were important to all dentists. Each practitioner should have had a sound concept concerning the condyle/disc/fossa relationship because of its importance to long term stability and function of the masticatory system. While a great deal has been written about "centric relation", there has been no general agreement on the relationship between the occlusion and the centric relation position. Research has continued to seek an answer to the question, what is the ideal relationship of centric occlusion and centric relation? Practitioners and researchers have worked for many years to find that ideal relation.

In the "Glossary of Prosthodontic Terms" established by the Academy of Denture Prosthetics, and in most dental literature, the definitions of centric relation have suggested that it has been the rearmost, uppermost, midmost position of the mandibular condyle in the glenoid fossa from which lateral movements can be initiated. This was the definition of centric relation which was taught in dental schools in 1981 and still adhered to in many today.

Earlier definitions described centric relation as the most retruded position of the condyles. Since the most retruded position was determined mainly by ligaments of the temporomandibular joint, it has also been called a ligamentous position. It became useful to the prosthodontist because it was a reproducible mandibular position that was used during the construction of complete dentures. This definition of centric relation became the most reliable mandibular reference point during full denture construction.

The importance of centric relation in fixed prosthodontics was substantiated both by its reproducibility and by research studies associated with muscle function. Studies of electromyographic (EMG) recordings indicated muscle function was more harmonious and less intense when the condyles were in centric relation during maximum intercuspation. The dental profession generally accepted these findings and concluded that centric relation was a sound physiologic position and designated the position of the mandible when the condyles were in the terminal hinge position.

Controversy still existed regarding the exact definition and position of the condyle disc assembly in centric relation. Clinical investigations dealt with condylar path movements, transcranial radiography, characteristics of range of movement studies, and auscultation of the temporomandibular joints. Many practitioners, educators, and authors did not agree with the earlier definition of centric relation as the most retruded or posterior position of the mandible. They agreed with a definition given by Farrar in 1973: "Centric relation is the most superior position of the condyles at which a hinge axis movement can be recorded, provided the articular discs are not displaced."

The purpose of this study is to compare two widely used clinical techniques of obtaining a centric relation registration. One technique is a muscle determined condylar position and the other is an operator guided condylar position. Both techniques try to obtain a physiologic condylar position and are currently advocated by leaders in the orthodontic community.

CHAPTER II

Review of Literature

The evolution of centric relation has mirrored the advancements made in occlusion but more specifically dentistry. For many years, dentists have attempted to identify and to define concepts of occlusion that could be applied to the dentition in diagnostic and therapeutic situations. It was difficult to discuss the concept of centric relation without being familiar with the history and principal issues involved in occlusion.

There were two basic concepts of occlusion. The first was termed balanced occlusion and the second was a mutual protection occlusion. Balanced and mutual protection concepts both referred to a functional relationship between the dental arches and the characteristic lateral and protrusive dynamics embodied in each approach. A balanced occlusion was one in which simultaneous and equal contacts were maintained among opposing tooth surfaces throughout the entire arch and throughout the entire excursion. Lateral excursion in a balanced scheme implied simultaneous bilateral dental arch contact in which occlusal contacts were maintained on both anterior and posterior teeth as the mandible moved anteriorly into a protruded position. Mutual protection was defined as a selective pattern of

disclusion of contralateral tooth surfaces during similar mandibular excursions. By serving to disclude the contralateral side teeth during lateral excursion and the posterior teeth during protrusive incisal contact, the ipsilateral teeth protected the contralateral teeth or inclines.

The concept of a balanced occlusion was often credited to Ferdinand Graf Spee (1890), whose observations on the function of the natural teeth of humans led him to conclude that "As forward and backward gliding of the mandible takes place in a path of circular motion, such displacements can occur over longer distances without any need for the arches to separate from each other. Thus, masticatory efficiency was guaranteed. A separation of the occlusal surfaces was only inevitable in order to overcome the contact of strongly protruding upper and lower canines. This ought to be considered in the construction of dentures, not only to enable better mastication but also in order to avoid lever effects during chewing." Thus, the balanced occlusion concept of occlusal organization was born, particularly for complete denture prosthodontics. The importance of this was understandable in an era when loss of the natural teeth was almost to be expected and the construction of functioning artificial dentures was a significant problem.

The focus on balanced occlusion concepts continued into the 20th century. Alfred Gysi (1910) criticized the continued use of the simple up and down hinged articulator. He concentrated on recording individual condylar inclinations and developed methods to more accurately record the pathway of the condyle as it

translated anteriorly and inferiorly on the articular eminence. Gysi built several new articulators and extraoral tracing devices during this period that incorporated the ideas of Bonwill (1885) and Walker (1896). Gysi recognized the need to incorporate excursions on a horizontal plane, in an instrument but Bonwill's instrumentation was limited insofar as it did not allow for the influence of the articular eminence on the condyle path during protrusion or lateral excursion. As the mandibular member was advanced relative to the maxillary member, there was no inferior component to the path of the condyle. This was essential to accurately create a balanced occlusion. Gysi contended that the methods used by Bonwill and Walker were incorrect because the condyle path did not form a straight line but followed an S-shape line. He demonstrated this movement with a Gothic arch (needle point) tracing. He designated this angular configuration as the "Gothic arch tracing." Its apex represented the most retruded unstrained position of the mandible and was considered to be centric relation, the starting point from which anterior and lateral jaw movements were made.

During this time period, several principles concerning the hypothetical center of rotation of the mandible with respect to the maxilla were proposed. George S. Monson (1920) proposed the "spherical principle in the solution of the problem of human occlusion." Monson's theories were readily applied to clinical practice. His concept of occlusion was based on a geometric level that presupposed an optimal anatomical configuration and functional occlusal relationships. Whatever component

of the natural dentition was at variance with Monson's ideal was made consistent with that ideal or removed. According to Monson, "Elongated teeth must be reduced in their length and teeth that have been in excessive function built up to their proper occlusion, bringing the occlusion of all teeth to conform to the surface of the sphere having proper interlocking cusps to maintain them in their alignment. The teeth were then ground into the full range of occlusion."

Bilateral balance was a natural consequence of such an approach to occlusion, yet there was small chance of attempting to make functional activity conform to a geometric ideal. Although the spherical ideal had been shown not to be a naturally occurring characteristic (Dempster 1963), it remains today as a concept that was partially employed by some dentists in the occlusal rehabilitation of natural dentitions (Mann and Pankey 1963).

Monson's greatest contribution to occlusal concepts was recognizing that two schools of thought regarding movements of the human mandible had evolved. "The first believed that the shape and movement of condyles govern the occlusion of the teeth, while the second group contends that the occlusion of the teeth was the dominant guiding factor which determines the shape and movements of the condyles in the glenoid fossa." Monson was obviously in the latter group and the articulators he utilized reflected this concept, having a single midline pivot 10 cm above the occlusal plane, and no condylar mechanism.

These divergent theoretical approaches to understanding and reproducing mandibular function shared one essential therapeutic objective: a completely balanced occlusion for full-denture prostheses. Denture stability was important, and as a result the cross-arch, cross-tooth, and protrusive elements of balance were accepted. Balanced occlusion mandated continuous contact between multiple surfaces of teeth during eccentric excursions. Cross-arch balance referred to simultaneous contact of buccal to buccal and lingual to lingual cusps of working side teeth, while protrusive balance provided simultaneously contacting inclines of both anterior and posterior teeth during protrusion. Balance was equated with stability of the artificial denture base and was the accepted approach to restoring function to the edentulous patient.

In 1926, B.B. McCollum and a group of dental colleagues founded the Gnathological Society of California. They coined the term gnathology and defined it as the study of temporomandibular joint movements, their selective measurement, reproduction, and use as determinants in the diagnosis and treatment of occlusion.

McCollum and his associates developed their concept of occlusion. It was considered the "immutable and ideal nature of the relationship between the condyle and fossa", which in turn was responsible for guiding the mandible in its correct relationship to the maxilla. They dedicated themselves to restoring "ideal" function and anatomy. Natural dentitions that did not adhere to their predetermined criteria were considered to be pathological. As McCollum (1938) stated:

> There is a subtle pathology of function in every mouth, due entirely to the malrelation between the opposing teeth themselves and between the interdigitation of the teeth and jaw motions. This pathology has for some time been called malarticulation.

Thus, deviations between centric occlusion and centric relation were thought to be the result of malpositioned cusps and teeth, which were then altered to conform to the recorded positions and movements of the condyle. Therefore, centric relation could only be approached from an understanding of the relationship between the condyle and its articulation with the temporal bone.

McCollum believed, despite the temporomandibular joints being biological mechanisms, that they will provide definite, measurable, recordable movements that can be reproduced on an articulator. The belief was if an articulator could absolutely duplicate jaw relations and condylar movement, it would be possible to make teeth that occlude ideally. As a result, McCollum and Stuart (1955) developed techniques for recording mandibular movements and specialized instrumentation that embodied these two basic assumptions. McCollum created the hinge-axis locator, a device to precisely pinpoint the transverse axis of condylar rotation. The pantograph was also produced to record the three-dimensional movement patterns of the condyles during protrusion and lateral excursion. A fully adjustable articulator was also developed capable of following these recorded condylar pathways.

McCollum embraced the idea of a completely balanced occlusion for the natural dentition, the attraction being it was totally consistent with his concept of an idealized biomechanical mechanism. He used sophisticated techniques to achieve exquisitely balanced occlusal arrangements in the laboratory, which were then transferred to the patient's dentition. The presumed objectives were to maintain idealized occlusal contact throughout all excursions, coordinated in function with the stable condyle-fossa relationship, thereby eliminating potential tooth interferences during the ideal condyle positions and movements. This allowed for the distribution of occlusal contacts among as many teeth as possible. This resulted in reduced loading to individual teeth and the possible curtailment of periodontal breakdown.

In 1929, Clyde H. Schuyler published his first of many articles on occlusal concepts.

> This does not mean that all principles of occlusion pertaining to full denture prosthesis are applicable to the natural dentition, nor that it would be possible to obtain in other branches of dentistry the same degree of perfection in occlusal relations as may be produced in full denture restorations. While such perfection might be desirable, it is not altogether essential to the health and maintenance of the supporting structures of natural teeth. The term "balanced occlusions" is most applicable to restorations supported by soft tissue.

Similar to the gnathologists, Schuyler believed in harmony between centric relation and centric occlusion for the natural dentition. He did not, however, impose a set of rigid standards on the occlusion that, if lacking, was equal to pathology. This new concept, when applied to the natural teeth, was referred to as functionalism. It was defined as "such arrangements of the teeth as will provide

the highest efficiency during all the excursions of the mandible which are necessary to the function of mastication." Although this definition was vague, it had the effect of recognizing the essential difference between the edentulous and dentulous conditions and, most significantly, did not impose rigid anatomical standards on an idealized relationship between condylar movement and occlusal organization. His insights and articles not withstanding, Schuyler persisted in supporting essentially balanced occlusion during his early clinical years.

In 1935, Schuyler developed the first detailed technique for occlusal adjustment based on the careful grinding of specific inclines in contradistinction to the haphazard manner practiced by so many dentists, including prosthodontics, periodontists, and orthodontists, trying to achieve a "balanced occlusion". In agreement with the gnathologists and other dentists of the time, Schuyler believed there was a relationship between functioning occlusal inclines and potential stress to the periodontium, and his occlusal adjustment techniques were meant to ameliorate these stresses.

With time, however, like the gnathologists, Schuyler began to observe clinical failures of balance when applied to the restored natural dentition. In 1953, he stated, "In the natural dentition I fail to see the real value of contacts on the nonfunctioning side, as they do not reduce the application of stress being applied to the teeth on the working side, and their contact may be a contributing factor to traumatic injury." At this time, he started emphasizing the important influence of

incisal guidance as the "predominating factor" determining posterior occlusal morphology. This was consistent with his view that, although the direction of movement of the mandible was controlled by the muscles and temporomandibular joint's when the dentition is out of occlusion, "when the opposing teeth of the natural dentition come into contact, the guiding inclines of the teeth immediately assume almost complete control of the direction and the extent of movement of the mandible" (Schuyler 1958). His concepts thus included the importance of canine guidance and the "canine-protected occlusion" that was used for "the desired relief of stress upon the balancing inclines of posterior teeth" (Schuyler 1961).

During this period, many gnathologists were also changing their idea of the balanced occlusion concept as applied to the natural dentition. Several admitted the majority of cases did not stand the rigid test of time and were failures. Stuart and Stallard (1960) wrote, balanced occlusion in reconstructed natural dentitions often required injudicious increases in occlusal vertical dimension to achieve balance. Often there was instability of the occlusion and this frequently showed increased wear of the teeth and restorations. In addition, it provided poor group usage of the teeth.

Thus, some parallel ideas were evolving in the occlusal concepts of both the gnathologists and the functionalists. D'Amico (1961) studied the dentitions of pre- and post-European California Indians and concluded:

> the immediate change from their primitive culture to the modern European way of life eliminated the abrasive factors which caused

> rapid attrition of the teeth and reduction in the vertical relation of the mandible. The result of this sudden change was the development of the overlap relation of the upper incisors and cuspids. Evolutionary or organic changes do not develop in such brief periods.

When D'Amico emphasized the maxillary canines had the principal occlusal contact in lateral excursion and served to guide the closing movement of the mandible into centric occlusion, both the gnathologists and the functionalists came to speak of a cuspid guided mutual protection concept of occlusion. This concept was based on the premise that the teeth should act as specialized groups so that in centric relation or eccentric positions of the mandible certain teeth or groups of teeth were best able to withstand the occlusal loads and, in doing so, protected other teeth or groups of teeth from unfavorable forces.

There were many techniques developed to obtain interocclusal centric relation records as occlusal concepts evolved. The oldest method of determining centric relation was the Gothic arch (needle point) tracing proposed by Gysi in 1910. The Gothic arch technique was more time consuming than intra oral techniques and required accurately fitting bases and rims. Grasso (1968) studied the duplicability of arrow point tracings in dentulous subjects and found significant changes in the apex position of the tracings during one day and over a 29 day period. The same apex position could not be duplicated at intervals during a 29 day period.

Niswonger (1934) stated, during the act of swallowing the mandible travels from rest position to centric relation and back to rest position. Swenson (1953) wrote swallowing usually brings the mandible to a retruded position and was an aid in securing this relation. Boucher (1955) agreed the mandible tended to move toward the position of centric relation and to the level of occlusion when swallowing. Because of these statements, methods of recording centric relation by using the reflex of swallowing became vogue. On the other hand, Posselt (1959) found "during deglutition the mandible never moves back to the terminal hinge relation. The contact or near contact positions seemed to be on the path of the intra extreme (habitual) closure."

Walker (1962) compared two methods of recording centric relation: the swallowing method and the needlepoint tracing method. To obtain centric relation by the act of swallowing, he used metal studs embedded in the lower occlusion rim. The studs were opposed by soft wax in the upper occlusion rim. The needlepoint tracing method used was similar to Gysi's. An extraoral stylus was joined to the upper occlusion rim and adjusted to contact a flat metal surface attached to the lower occlusion rim at the vertical relation of occlusion. This relation was maintained by an intraoral central bearing device. As the mandible was moved to both the extreme right and left positions, the stylus scribed a tracing similar to a Gothic arch. The jaws were considered to be in centric relation when the stylus was at the apex of the tracing. Twenty-one edentulous subjects were used in this

study. Walker found the needlepoint method did not locate the mandible in the same position as the swallowing method. The needlepoint method was able to register centric relation in a more posterior relation to the maxilla than the swallowing method. Therefore, the act of swallowing was shown to be unreliable for obtaining centric relation according to the definition of centric relation at this time.

Abdel-Hakim (1982) also examined the swallowing method of determining centric relation. He studied the intraoral tracings of the swallowing position for six patients at the natural occlusal vertical dimension. Deviations of the position from the intercuspal position were measured. The swallowing position deviated antero-posteriorly and laterally from the interocclusal position, and this raised the question as to the validity of this method for recording centric relation.

Another method of locating centric relation and recording it was described by Lucia (1964). It utilized an anterior guidance prosthesis which was referred to as an anterior stop or jig. The anterior jig separated posterior occlusal contacting surfaces, altering occlusal sensation derived from the mechanoreceptors in the periodontal membrane space. Proprioceptive stimuli from tooth contacts in the maximum intercuspated position were eliminated. A tripodal relationship exists between the maxilla and mandible which placed the condyles in the uppermost and rearmost position within the fossa.

Strohaver (1972) studied four methods for making centric relation records. Each method involved a different recording material and different technique for recording centric relation. He compared these four methods to the Myocentric position (automatic stimulation by Myo-Monitor) and centric occlusion. The four methods were: 1) forceful guidance by the dentist recorded by zinc-oxide eugenol paste, bite frame and Lucia jig 2) forceful guidance by the dentist recorded in wax 3) voluntary retrusion by patient recorded in plaster 4) forceful guidance by the dentist recorded by acrylic resin and Stuart jig. One thirty-one year old graduate student served as the subject. He had a full complement of teeth with no signs of functional disturbances. Three dentists made a series of three interocclusal records by each of the methods described. He concluded that the zinc oxide and eugenol method utilizing a Lucia jig produced the least variable group of articulator mountings made with interocclusal records. This method also produced the most posterosuperior (retruded) relationships of the mandibular cast to the axis of the articulator. He also found the myocentric position records made with the Jankelson Myo-Monitor produced the most variable group of articulator mountings of all the methods tested.

Helkimo (1973) investigated six methods for active and passive recording of the retruded position. Ten male volunteers, aged 22 to 27 were selected irrespective of the type of occlusion. All had complete dentitions. None of the subjects had any demonstrable disorders of the masticatory system. The position

of the mandible was recorded with the intraoral graphic method. The precision of the recording of the retruded position was highest when recorded by passive hinge movement, and lowest when recorded by active hinge movement and active retrusion from habitual occlusion. No differences in the antero-posterior position of the mandible in the retruded position were found between the active and passive recordings with the exception of the so called "moderate chin guidance". This resulted in a more anterior mandibular position than the other methods, but still in the retrusive area, posterior to habitual closure.

Celenza (1973) studied four different methods of centric relation registrations; 1) unguided biting point, 2) unguided Gothic arch tracings, 3) guided biting point, and 4) guided Gothic arch tracing. Fifteen subjects were studied. All had Angle Class I occlusions. Registrations were taken four times for each method on each subject. In five subjects, this procedure was repeated three times at one week intervals. The results based on this experiment were as follows: 1) The most duplicable method was the guided biting point method. 2) The most retrusive position was the most replicable position. 3) Guided registrations were more consistent than unguided registrations. 4) In four of the five subjects who were tested over a 21 day period at one-week intervals, there did not seem to be any influence of time on consistency and dispersion patterns.

Dawson (1974) advocated bilateral manipulation of the mandible to encourage anterior-superior placement of the condyles. He believed centric relation

was "not unstrained because it is achieved by firm contraction of the elevator muscles. It was not the most retruded position because it was possible to force the condyles distal to centric relation, but such distal displacement occurs only with a downward movement away from centric relation. The centric relation position occurs at an apex of force position. In order for the condyles to move either forward or backward of centric relation, they must also move downward." Dawson believed this technique allowed replicability of the mandibular position. He also stated that one handed techniques such as chin point guidance tend to unseat the condyles downward and backward.

Long (1970) had previously tested chin point guidance but his observations were based on six consecutive recordings performed on one subject. They were found to be progressively more inferior and posterior along an almost straight line.

Kantor (1973) studied replicability and spatial patterning of intermaxillary records obtained utilizing four techniques: 1) swallowing, 2) chin-point guidance, 3) chin-point guidance with anterior jig, and 4) bilateral manipulation. Fifteen subjects were studied between the ages of 21 and 45. Six records were made with each technique. The data was analyzed in relation to consistency and displacement patterns. He found bilateral manipulation produced the smallest area of displacement and greatest consistency. Three of the four subjects in whom bilateral manipulation did not produce the most consistent results displayed inconsistent records regardless of the technique employed. The most protrusive positions were

recorded with the technique of free closure and Myo-monitor. The most retrusive records were produced when the technique of chin point guidance was combined with an anterior jig.

Simon and Nicholls (1980) compared the repeatability of chin point guidance with an anterior jig and bilateral manipulation in patients free from clinical signs and symptoms in the temporomandibular joints and masticatory muscles. In this study, chin point guidance with ramus support was also tested. Five female subjects between the ages of 20 and 30 were selected. Using mounted casts and inter-occlusal indices, they concluded centric relation may be considered a small range of mandibular positions. There was no significant difference between the ranges of mandibular positions recorded using chin-point guidance, chin-point guidance with ramus support, or bimanual manipulation. They also concluded that this technique of comparing mandibular positions dictated by centric relation records was sufficiently sensitive to reveal minimum ranges of biologic variation.

Levinson (1982) compared the anterior biting jig method with the bilateral manipulation technique. Four dental students were selected with unmutilated dentitions and no subjective symptoms of dysfunction of the masticatory system. Ten registrations of centric relation were made for each patient, five using the bilateral manipulation technique, and five by the anterior biting jig method. The two techniques were performed by different operators. The Denar Varicheck instrument was used to analyze the data in three dimensions. He concluded the

recordings made by the anterior biting jig method were more reproducible than those made by the bilateral manipulation method. He also found the anterior biting jig method consistently recorded a more superior and anterior position.

Hellsing (1983) studied recordings of the most retruded position of the mandible using a one-handed pushback technique versus the bilateral manipulation technique. In this study, radiographic comparison of both condylar positions in 15 healthy subjects having good occlusions failed to reveal any significant difference. Clinically, however, the first tooth contacts achieved with the bilateral manipulation technique tended to be more posterior to those obtained with the push back technique.

Capp (1985) described a technique for evaluating centric relation tooth contacts. He compared the initial contacts using an anterior occlusal stop with chin point guidance method against the bilateral manipulation method. He used one subject with no signs of temporomandibular joint dysfunction. Ten registrations were made using chin point guidance and an anterior occlusal stop. Ten additional registrations were made using bimanual manipulation and no anterior occlusal stop. The two methods were alternated so that potential subject fatigue did not bias the result. He concluded the anterior occlusal stop produced a centric relation position more posterior than that found with bimanual manipulation. There was no statistically significant difference in the vertical and mediolateral planes.

Lee (1987) studied the reproducibility and position of centric and myocentric relation. The following positions of the mandible were registered: 1) centric relation manipulated by means of the chin-point technique with a Lucia-jig, 2) centric relation manipulated by means of a bilateral technique, and 3) myocentric manipulated by the Myo-Monitor. Eight dental students and dentists who had no missing teeth and no difficulties with mandibular movement were selected. A Vericheck instrument was employed by examining the difference in the position and reproducibility of the mandible reproduced by the various check bite records. Analysis of the data indicated that the bilaterally manipulated centric relation was more reproducible than myocentric in the anteroposterior and superoinferior position and more reproducible than centric relation manipulated by means of the chin-point technique with the Lucia-jig in anteroposterior position. Centric relation manipulated by means of the chin-point technique with the Lucia-jig was more reproducible than myocentric in right anteroposterior and superoinferior position.

Another method of recording centric relation utilizing an anterior guidance instrument was described by Long (1973). This instrument was referred to as a leaf gauge. The gauge was placed between the anterior teeth and the patient was asked to bite on his posterior teeth. If any posterior teeth began to touch, another leaf was added. When the patient was able to close on the leaf gauge for approximately 5 minutes without posterior tooth contact, the mandibular condyles were considered to be in anatomically dictated centric relation. Williamson (1981) popularized this

technique using a period of five minutes since Jarabak (1956) indicated aberrant neuromuscular electromyography recordings return in that amount of time when an interocclusal splint was removed.

Williamson (1980) compared a muscle determined position to an operator guided position. He used fifteen subjects to determine direction and magnitudes of shifts in condylar position when interocclusal records were made by biting hard or easy on a leaf gauge or wax. Results indicated no significant difference in condylar position superoinferiorly between registrations. Biting hard on a leaf gauge caused a significantly more posterior position of the condyle. When this technique is used for obtaining interocclusal registrations, the temporal muscles are more active than the masseters.

Dr. Ronald Roth (1985) recommended a centric bite registration technique called "Power Centric". A "power" centric registration refers to a registration that was taken using blue delar wax in the anterior section of the mouth that used operator guidance and required some muscular contraction on the part of the patient to achieve tooth indexing. This technique utilized the patient's own musculature to seat the condyles in centric relation. The lateral pterygoid muscles were used to seat the condyles into centric relation without triggering the masseter muscles.

The aim of this study was to compare two techniques of obtaining centric relation registrations. One technique was a muscle determined position using a leaf

gauge to locate a seated condylar position (Williamson). The other technique was an operator guided technique called the "Two-piece Delar power centric registration" advocated by Dr. Roth.

The two techniques will be compared using the mandibular positioner indicator in conjunction with the SAM II articulator system. This will allow for a quantifiable determination of condylar position. This study will further analyze the repeatability of each technique.

CHAPTER III

Materials and Methods

Selection and characteristics of the sample:

Twenty-eight freshmen dental and hygiene students were selected. Their average age was 23.3 years old. There were fifteen males and thirteen females. The main criterion for selecting patients was the absence of signs and symptoms of mandibular dysfunction including:

a) no palpable masticatory muscle or temporomandibular joint pain

b) no limitation of mandibular movement (active opening greater than 40 mm.).

c) no temporomandibular joint noises.

d) no history of mandibular dysfunction

e) dental arch integrity without fixed or removable prostheses.

Exam - Informed Consent - Records:

Each subject was scheduled for a one hour exam. A head and neck exam was performed to select subjects to meet the above mentioned prerequisites. Descriptions and explanations of the procedures to be used during this study were clarified and an informed consent document was signed. (Appendix A) Dental

alginate (Jeltrate - fast set, Caulk Dentsply) impressions were taken of the maxillary and mandibular arches and poured in dental stone (Whip Mix Silky Rock). An estimated anatomical face bow procedure was performed so that the maxillary cast could be mounted on the SAM II articulator. A pink piece of Moyco wax was used to take a centric occlusion bite for reference purposes. Each subject was then scheduled for four additional appointments.

Research Model:

Two independent operators were used to perform the mandibular recording techniques. Each operator performed each technique three times at two different sessions one month apart. This enabled intra-operator and inter-operator reliability to be tested. If the reliability was confirmed it could then be used to test the sensitivity of the two recording techniques over time. Since two operators were to perform each technique, the following schedule was devised.

	Day 1	Day 2	Day 3	Day 4
Operator 1	technique 1	technique 2	technique 1	technique 2
Operator 2	technique 2	technique 1	technique 2	technique 1

At each appointment, three interocclusal centric relation registrations were taken using each technique. The Roth technique was always performed first since the leaf gauge required a few minutes to deprogram the mandibular musculature.

Appointments three and four were scheduled thirty days after appointments one and two to allow for comparisons of the centric relation registrations using time as a variable.

The two techniques for obtaining centric relation interocclusal records were learned first hand by both operators and performed to the exact specifications of the respective experts. Dr. Ronald Roth of San Mateo, California and Dr. Eugene Williamson of Evans, Georgia taught their techniques to the operators participating in the study to minimize errors attributable to technique duplication.

Leaf Gauge Technique: (Williamson, 1986)

1. Each subject had their mandible manipulated by placing the index and second figures on the inferior surface of the right and left gonial angles. The thumb of the same hand was placed on pogonion. With upwards pressure on the gonial angles and downward pressure on pogonion, the mandible was rotated to the seated position as best as possible. The subject closed from that position to first tooth contact while manipulation of the mandible continued. The amount of space between the maxillary and mandibular incisor teeth was assessed.

2. An approximate number of leaves were selected to fill the space needed between the maxillary and the mandibular incisors and three more leaves were added in order to separate all the posterior teeth. (figure 1)

3. The leaf gauge was placed with the selected number of leaves between the incisor teeth. A thumb was placed on the posterior teeth of one side and the first finger on the teeth in the second molar area of the opposite side. While tapping the mandibular molars, the subject was asked to "try to bite on the back teeth on both sides at the same time". (figure 2)

figure 1

figure 2

4. The fingers were removed from the oral cavity and the operator stood behind the patient. The tips of the fingers were placed on the anterior to middle fingers of the temporalis muscles bilaterally. If the subject was biting correctly, the bulging contraction of the muscles was felt simultaneously. The masseter muscle should not be contracting with this mandibular movement.

5. The subject was asked to place his fingers on the temporalis muscles bilaterally above the ears. He was instructed to use the tips of his fingers and press firmly. At the same time, the subject placed his thumbs on the masseter muscles as shown in figure 3. The subject was told contractions should be felt from the temporal but not the masseter muscles if he was biting correctly. This proprioceptive feedback was very important to the patient. If he could feel the muscles contracting properly, he was able to repeat the technique routinely.

figure 3

6. The subject was told to "squeeze and relax, squeeze and relax" and to bite with moderate pressure. He was instructed not to bite hard except initially to be able to feel muscle contraction.

7. When the subject completed this procedure for five minutes with only the temporalis muscles contracting and without posterior tooth contact, an interocclusal record was made. The mandible was assumed to be in the seated position for that subject at that appointment. If the teeth began to contact, a few more leaves were added and the subject was asked to continue the procedure until only temporalis function occurred and no posterior tooth contacted.

8. Bite forks with formulator mesh were prepared prior to each subject's appointment as shown in figure 4. Zinc oxide and eugenol paste (Surgident, Columbus Dental) was loaded on to the formulator mesh covering only areas of upper and lower posterior occlusal contact. The bite fork was placed into the subject's mouth with the leaf gauge in place and asked to bite into the leaf gauge as previously instructed. (figures 5&6) The firmness of the zinc-oxide eugenol paste was tested with an explorer before the bite fork was removed from the mouth. (figure 7) The bites were trimmed to enable the mandibular cast to be mounted on the articulator.

figure 4

figure 5

figure 6

figure 7

Power Centric Bite Technique: (Roth, 1986)

1. Sheets of Delar bite registration wax (Almore International) were warmed in a waterbath set at 135 degrees F. They were then folded and cut into two separate sections. The anterior piece was five layers thick and cut to cover the incisors and cuspids. The posterior section of wax was two layers thick and cut to cover the second bicuspid and first molar. (figure 8)

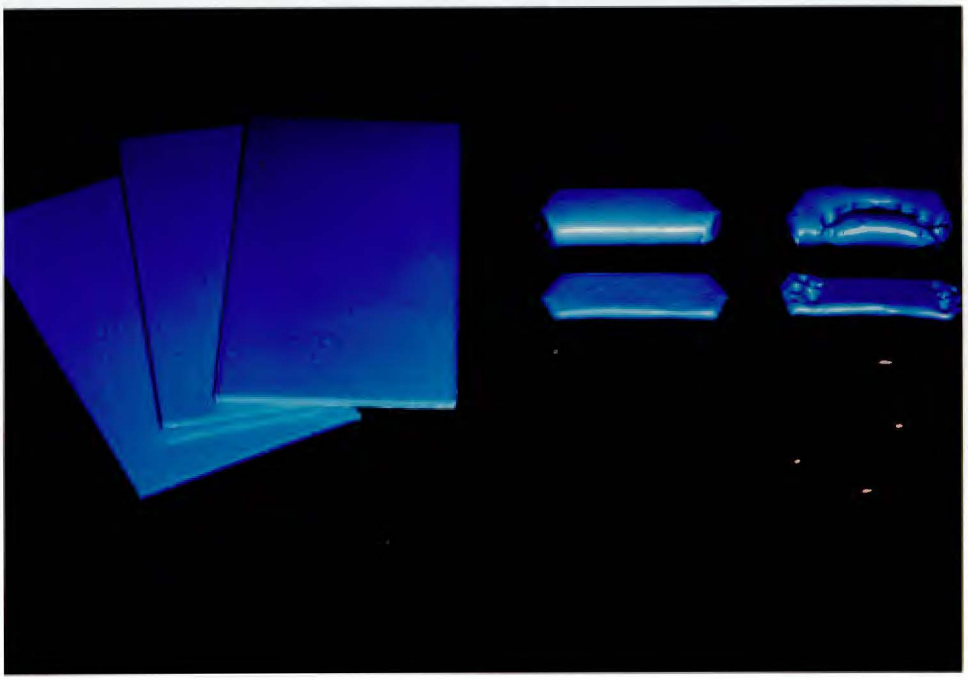

figure 8

2. The subject was reclined in the dental chair at a 45 degree angle and the softened anterior section of wax was placed over the subject's maxillary teeth, while the subject was instructed not to close. (figure 9)

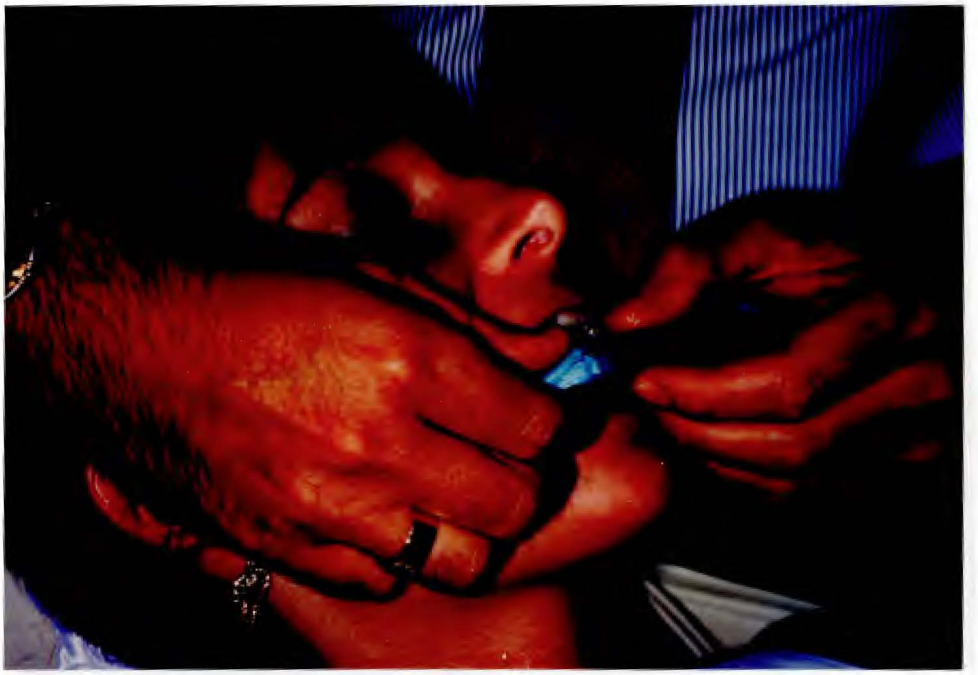

figure 9

3. The operator placed his thumb on the chin pushing downward with index and second finger extended on the inferior borders of the mandible pushing slightly upward as shown in figure 10. The wrist and forearm of the operator were stiff, the elbow bent at an angle of 90 degrees with the forearm and wrist forming a line that passed through the patient's temporomandibular joints.

figure 10

4. The patient was then instructed to bite halfway. Once the mandible had moved distally, the subject was instructed to "hinge" slowly closed until his lower front teeth touched the blue wax.

5. While holding the mandible firmly, the operator guided the mandible keeping the forearm and wrist rigid. The subject was instructed to "hinge" closed a small amount at a time into the wax until the posterior teeth were two millimeters apart. The wax was cooled with air and removed from the subject's mouth and placed in a cold water bath to harden. (figure 11)

figure 11

6. The soft posterior section of wax was placed on the maxillary posterior teeth and supported with the operator's fingers on the buccal surfaces. While holding the posterior section in place, the anterior section was replaced on the maxillary teeth. (figure 12)

7. The mandible was guided into the hard anterior section of wax. The mandibular anterior teeth fit closely into the hardened anterior section of wax. As the patient closed into the hardened anterior section, the subject was asked to "close firmly and hold it". Air was used to chill the posterior section intra-orally. (figure 13) Both sections of wax were removed from the mouth and chilled in cold water. (figure 14) The bites were trimmed with a scalpel to enable the mandibular casts to be mounted on the articulator.

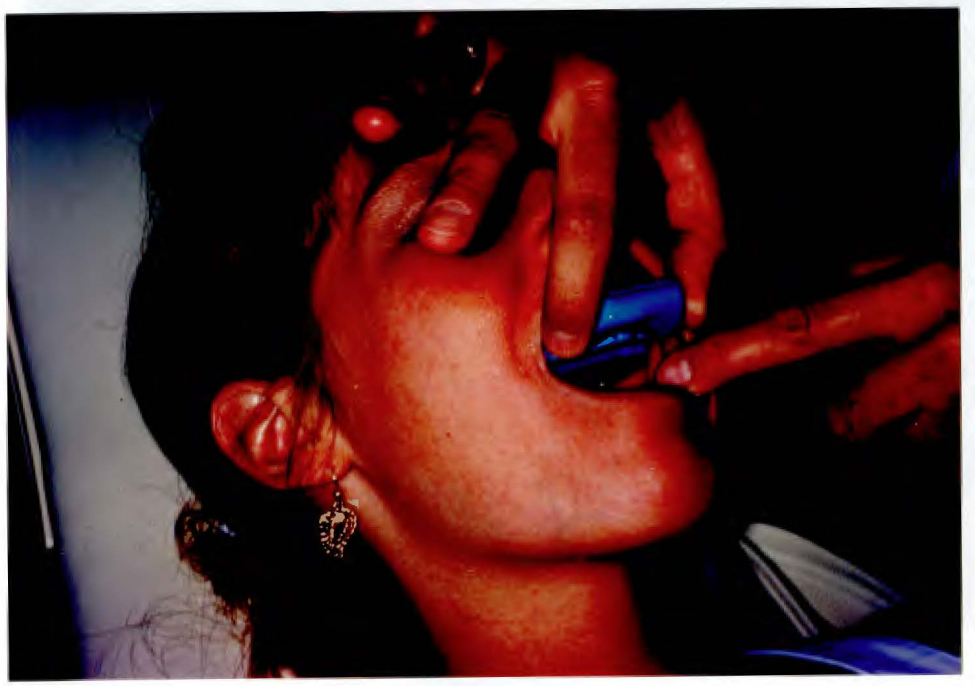

figure 12

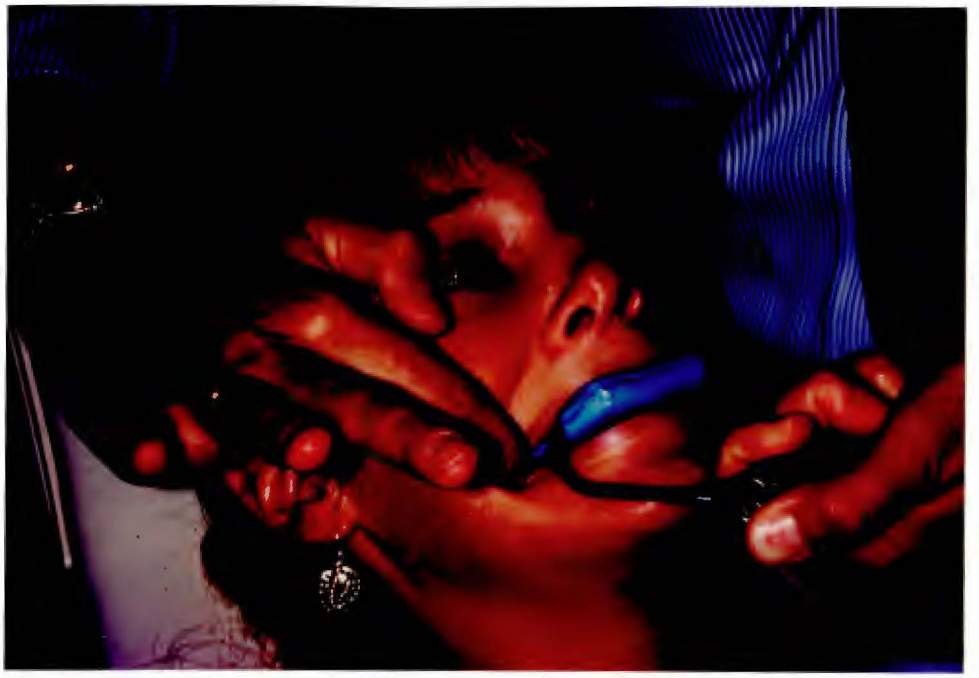

figure 13

figure 14

Model Preparation:

The alginate impressions were rinsed with water and lightly air dried. They were immediately poured with improved dental stone (Whip Mix Silky Rock) and allowed to set according to manufacturers specifications. The models were rough trimmed and any occlusal bubbles of stone were removed to allow for articulator mounting.

SAM System - Mandibular Position Indicator - Magnetic Split Cast Former

The SAM system (Great Lakes Orthodontics) provided instrumentation for functional diagnosis, therapy and research. The SAM Anatomical Transfer Bow (ATB), SAM II Articulator, Magnetic Split-Cast Former (MSF) and Mandibular Position Indicator (M.P.I.) were the components of the SAM system used in this study.

The ATB was used to mount each subject's maxillary cast to the SAM II Articulator. Using nasion and the external auditory meati, the ATB was oriented to the axis orbital plane. (figure 15) The MSF was used during the mounting of each subject's case to permit the removal of the maxillary cast from the primary base attached to the articulator. The split cast technique was a simple method for comparing interocclusal records and testing repeatability.

The M.P.I was a three dimensional measuring instrument that was a modified upper member of the SAM articulator and used to record changes in condylar

positions. It recorded changes in condylar positions and allows direct interpretations of condylar positional changes. (figure 16) All M.P.I. measurements were made within the instruments' inter-condylar distance and relate to the hinge axis. The horizontal and vertical measuring points were located on sagittal planes next to the medial surfaces of the condylar elements. They were read off of a grid sticker with one millimeter squares. (figure 17) Medial or lateral changes were measured directly on the horizontal hinge axis from the medial condylar poles. They were read on a precision dial gauge in millimeters (figure 18).

figure 15

figure 16

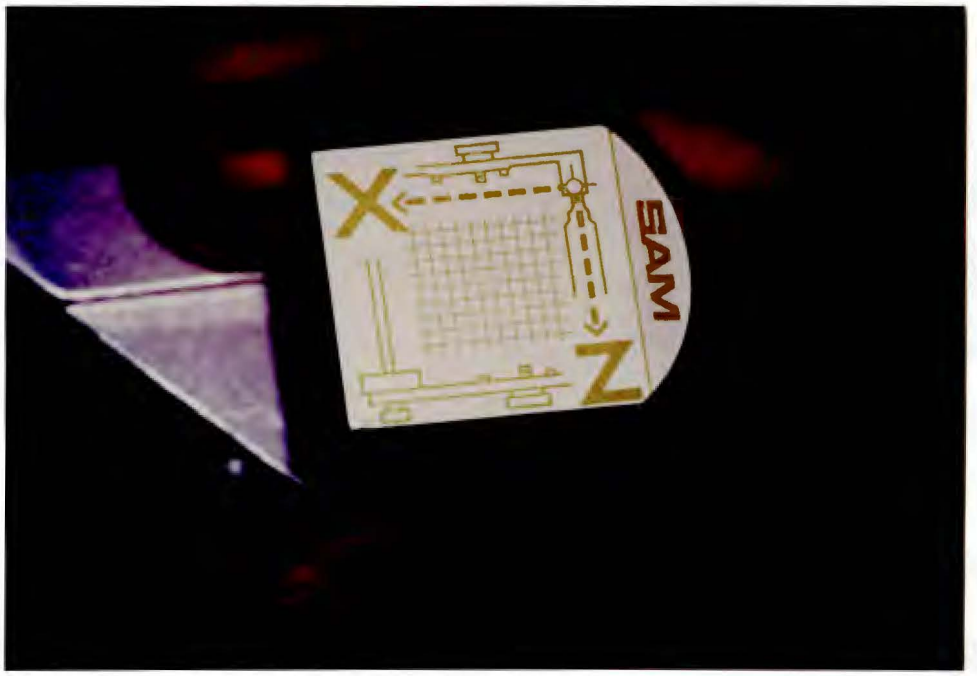

figure 17

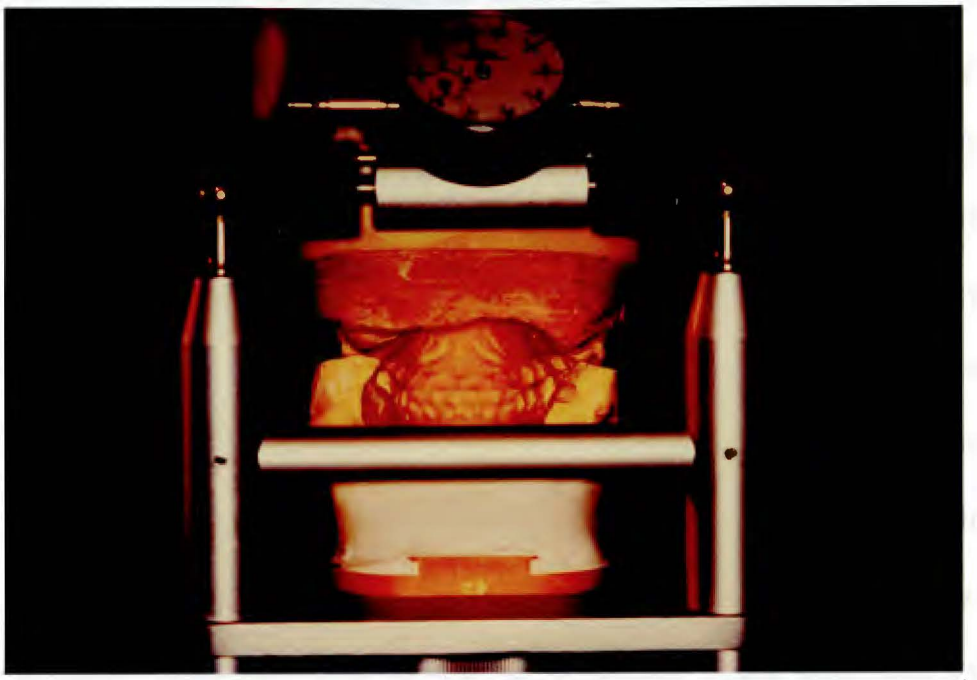

figure 18

Raw Data Collection:

The three interocclusal registrations of each technique were treated as a set. The second registration was used to mount the mandibular cast. Since the maxillary cast was mounted using the ATB and MSF, the first and third registration were checked to determine repeatability. Figure 19 illustrated a mounted set of casts using the second registration. Figure 20 illustrated how the magnet was removed from the split cast. Figure 21 demonstrated how the first and third registration were placed between the maxillary and mandibular cast. The incisal pin was lowered so that it would not influence the closure. The maxillary member of the

articulator was replaced so the condyles were well seated and locked (figure 22). The upper member was slowly closed. If the split cast did not fit perfectly, it indicated the present registration was different than the registration used for mounting the mandibular cast. (figure 23) If the split cast fit perfectly, it indicated the present registration matched the registration used for the mounting. (figure 24)

After determining how many registrations matched for each technique, operator and time, the most repeated centric relation position (C.R.) was selected to analyze the three dimensional position of the condyles for each of the techniques and operators. The M.P.I. was used to obtain measurements in the horizontal "X" (antero-posterior) dimension and vertical "Z" dimension which were read from the condylar grids. The lateral "Y" (medial-lateral) dimension was read from the transverse recording dial gauge on the M.P.I. The "X" and "Z" measurements had right and left condylar readings.

While the maxillary cast was mounted on the M.P.I., right and left condylar readings were recorded. Since the casts were mounted with C.R. registrations, the pin point hole on the condylar grid sticker represented C.R. position. The pin perforated the graph paper by sliding the black block inward. The C.O. position was marked with blue carbon paper by sliding the black block against the carbon paper and condylar ball while the pink centric occlusion registration was between the maxillary and mandibular casts. (figures 25 & 26) The pin point holes were marked red to delineate C.R. (red) from C.O. (blue). "X" and "Z" measurements

were read from the right and left condylar grid stickers. Measurements were read according to the graph in figure 27. The following example illustrated a set of "X" and "Z" measurements taken from one condylar grid sticker (figure 28). Centric occlusion (blue dot) served as the reference point. The right condylar sticker located on the left had an "X" measurement of 0.5 mm. and a "Z" measurement of -3.0 mm. The left condylar sticker located on the right had an "X" measurement of 0.0 mm. and a "Z" measurement of -3.0 mm.

The last measurement recorded using the M.P.I. was the side-shift or medio-lateral shift ("Y") between C.R. and C.O. The precision dial gauge (figure 29) had black and red numbers representing millimeters. Black measurements represented a right condylar shift. A right condylar shift was labeled positive and a left condylar shift was labeled negative. The dial gauge in figure 29 held a -1.07 measurement which represented a left condylar shift.

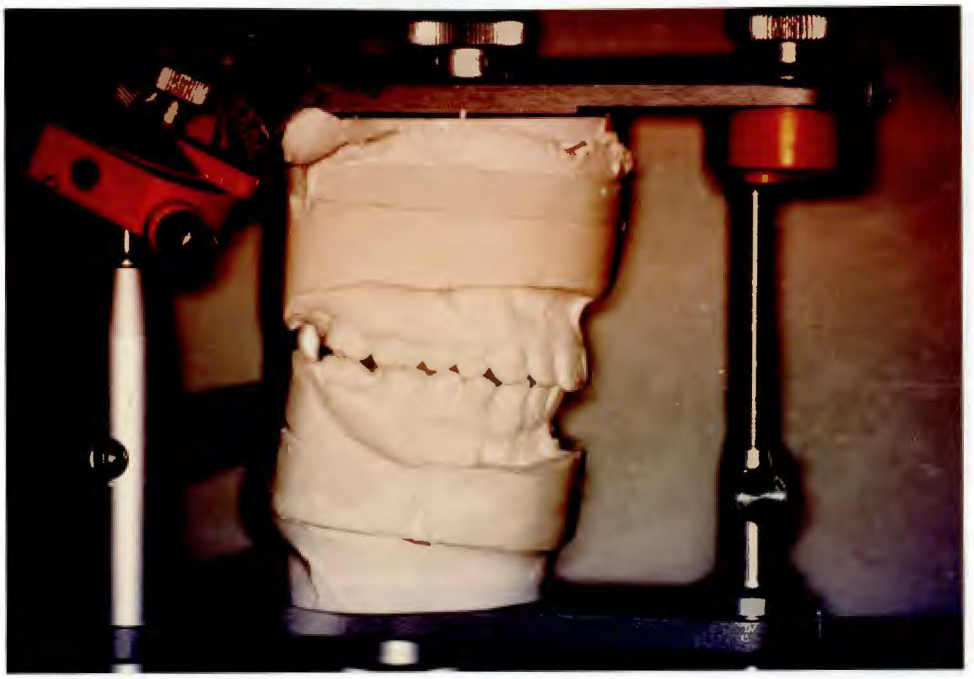

figure 19

figure 20

figure 21

figure 22

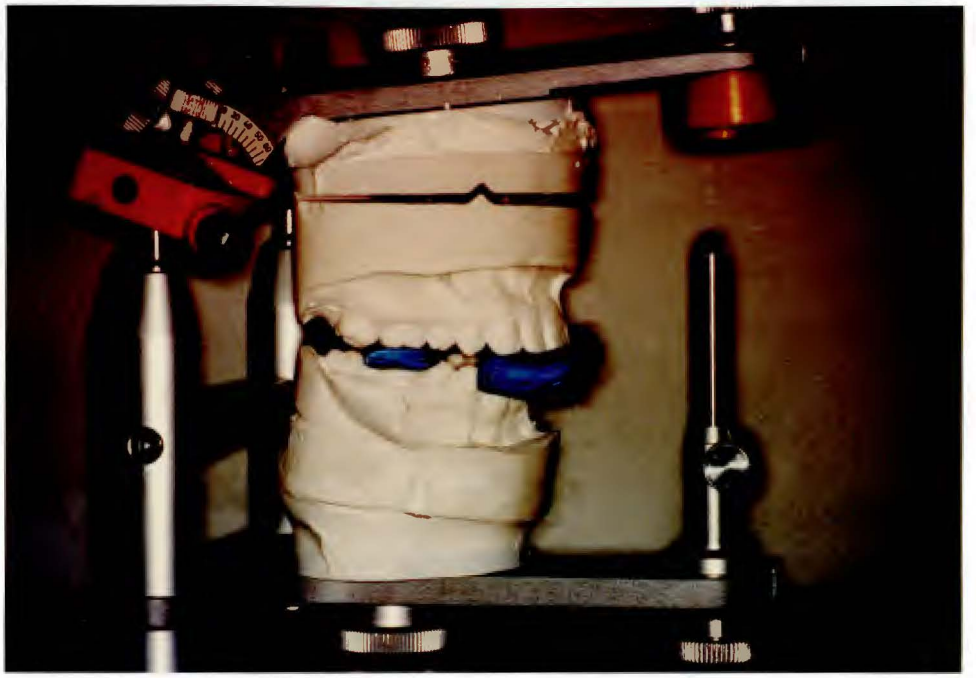

figure 23

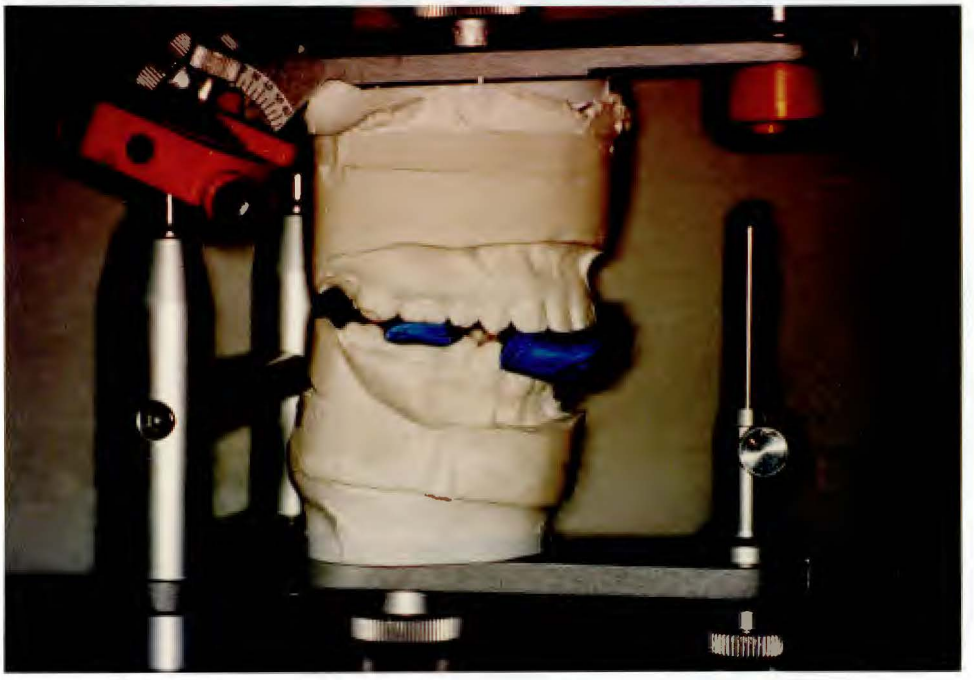

figure 24

figure 25

figure 26

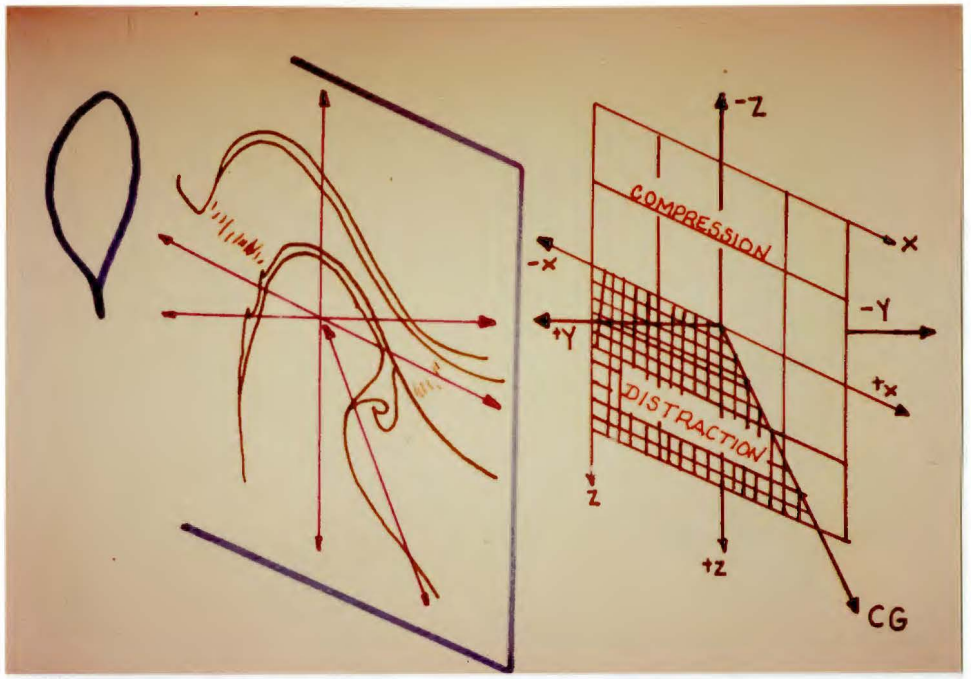

figure 27

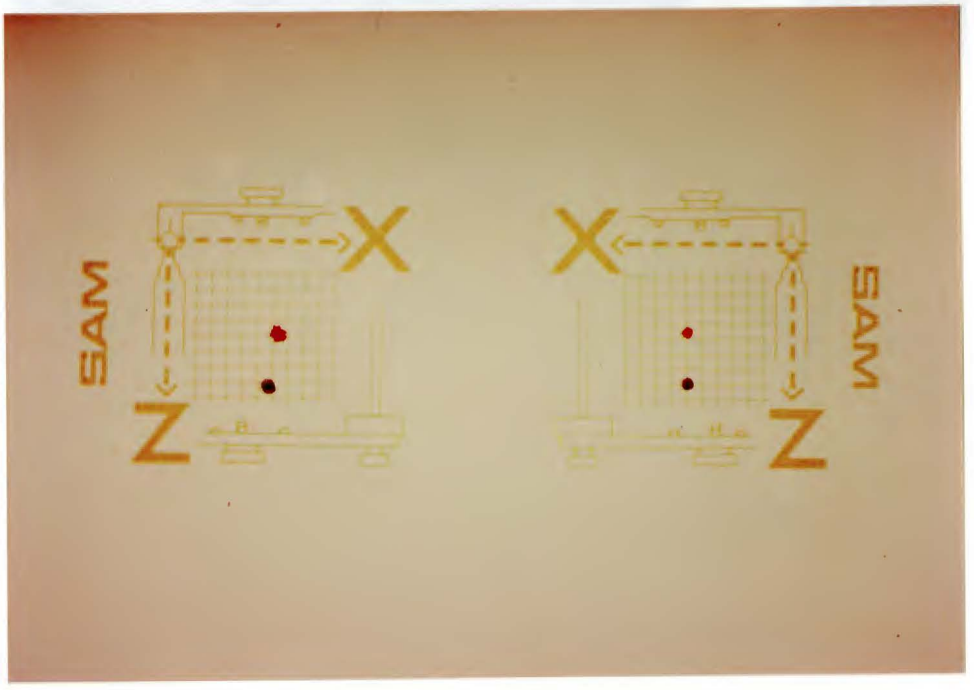

figure 28

figure 29

Statistical Treatment of Data:

The purpose of this investigation was to compare two techniques. The split cast technique tested the respective techniques repeatability and reproducability after 30 days (one month) as illustrated in Great Lakes Orthodontics' Manual on the SAM 2 System (Gugino, 1984). The M.P.I. readings ("X", "Z" and "Y") were averaged and the maximum and the minimum measurements, variance and standard deviations were calculated for each technique and operator. Paired t-tests were used to compare intraoperator reliability, interoperator reliability and intertechnique reliability.

CHAPTER IV

Results

Tables I and II present the data collected using the split cast technique for each operator respectively. The first column listed is the subject number. The second column represents the number of bite registrations which matched during the initial appointment the leaf gauge technique (LG) was used. The third column is the number of bite registrations which matched the previous bite registrations thirty days later. An asterisk is used to denote that a second mounting was necessary if no bite registrations matched the previous bite registrations. This needed to be done for subject 2 operator 1 and subjects 1, 3, 4, 5 and 21 operator 2 during the leaf gauge technique. It was not necessary for any of the subjects during the power centric technique. Columns four and five represent the equivalent information as columns two and three except for the power centric technique (PC).

Tables III, IV, V, and VI contain the data collected using the Mandibular Position Indicator (M.P.I.). Each table represents one operator and one technique. The measurements "X" Right, "X" Left, "Z" Right, "Z" Left and ABS "Y" are listed in column one. The average, maximum, minimum, variance and standard deviations are listed for each measurement. A negative value for the horizontal ("X")

measurement represents a posterior displacement of the respective condylar element. A negative value for the vertical ("Z") measurement represents an upward (compression) displacement of the respective condylar element. All averages for "X" and "Z" for both operators and techniques were negative. This represented a posterior and superior displacement from centric occlusion (C.O.) to centric relation (C.R.).

The statistical analysis for the data obtained in this study is found in Tables VII, VIII and IX. Table VII represents a statistical evaluation of intraoperator reliability thirty days apart for each technique. A paired t-test was performed for each measurement to ascertain whether there was a statistically significant difference for any measurement for operator or technique ($p \leq 0.01$). It is evident from the calculated t values that there might be less reliability using the leaf gauge technique as compared to the power centric technique.

Table VIII represents a statistical evaluation of interoperator relability. Paired t-tests were performed for each measurement between operators for the power centric technique and the leaf gauge technique. There is no statistically significant difference between the operators for any measurement utilizing each technique ($P \leq 0.01$).

Table IX represents a statistical evaluation of intertechnique reliability. Since no statistically significant differences were found between the techniques thirty days apart or between the two operators for each respective technique, a paired t-test

was performed between operator one's power centric measurements and operator two's leaf gauge measurements. No statistically significant difference was found to exist for any measurement between two operators irrespective of technique ($P \leq 0.01$).

TABLE 1

Number of Matched Registrations Using Split Cast Technique

Operator 1

Total Number of Subjects = 28

Subject	LG	30 Days Later	PC	30 Days Later
1	2	3	3	3
2	3	3*	3	3
3	3	3	3	3
4	3	3	2	2
5	2	3	3	2
6	3	3	3	3
7	3	3	2	3
8	2	3	3	3
9	3	2	3	3
10	3	3	2	3
11	2	3	3	3
12	3	3	3	2
13	3	3	3	3
14	3	3	3	3
15	3	3	3	3
16	2	3	3	3
17	3	3	3	3
18	3	3	3	2
19	3	3	3	3
20	3	3	3	3
21	3	2	3	3
22	3	2	2	3
23	2	3	3	3
24	2	2	2	3
25	3	3	3	3
26	3	3	3	3
27	3	3	3	3
28	2	3	3	2

*denotes remounting of case necessary because no bite registrations matched previous mounting

LG = leaf gauge technique PC = power centric technique

TABLE II

Number of Matched Registrations Using Split Cast Technique

Operator 2

Total Number of Subjects = 28

Subject	LG	30 Days Later	PC	30 Days Later
1	2	3*	3	2
2	2	3	3	3
3	3	3*	3	3
4	3	3*	2	3
5	2	3*	3	3
6	3	2	3	3
7	3	3	3	3
8	3	3	3	2
9	3	3	2	3
10	0	3	3	3
11	3	3	3	2
12	3	2	3	3
13	3	3	3	3
14	3	3	3	3
15	3	3	3	3
16	3	3	3	3
17	3	3	3	3
18	3	3	3	3
19	3	3	3	3
20	3	3	3	3
21	3	3*	2	3
22	3	3	3	2
23	3	3	3	3
24	2	3	2	3
25	2	3	2	1
26	3	3	3	3
27	3	2	3	3
28	3	2	3	3

*denotes remounting of case necessary because no bite registrations matched previous mounting

LG = leaf gauge technique PC = power centric technique

TABLE III

MPI Readings

Power Centric Technique

Operator 1

Total Number of Subjects = 28

Measurements in mm	Average	Max.	Min.	Var.	Std.
_____ "X" Right	-0.52	1.00	-5.00	1.96	1.42
_____ "X" Left	-0.64	1.50	-5.00	1.46	1.23
_____ "Z" Right	-1.29	1.50	-3.50	1.15	1.09
_____ "Z" Left	-0.93	1.50	-3.00	0.96	1.00
_____ ABS "Y"	0.65	2.50	-0.50	0.34	0.59

TABLE IV

MPI Readings

Leaf Gauge Technique

Operator 1

Total Number of Subjects = 28

Measurements in mm	Average	Max.	Min.	Var.	Std.
_____ "X" Right	-0.27	1.50	-2.50	0.74	0.88
_____ "X" Left	-0.71	1.00	-3.50	1.03	1.03
_____ "Z" Right	-1.02	1.00	-3.40	0.96	1.00
_____ "Z" Left	-0.71	2.50	-2.50	1.19	1.11
_____ ABS "Y"	0.72	1.90	0.00	0.23	0.48

TABLE V

MPI Readings

Power Centric Technique

Operator 2

Measurements in mm	Average	Max.	Min.	Var.	Std.
_____ "X" Right	-0.43	1.00	-2.50	0.80	0.91
_____ "X" Left	-0.59	1.50	-3.50	1.22	1.12
_____ "Z" Right	-1.23	1.00	-3.50	1.12	1.08
_____ "Z" Left	-1.29	1.00	-3.00	0.65	0.82
_____ ABS "Y"	0.45	1.80	-1.50	0.41	0.65

TABLE VI

MPI Readings

Leaf Gauge Technique

Operator 2

Measurements in mm	Average	Max.	Min.	Var.	Std.
_____ "X" Right	-0.30	2.00	-3.00	0.83	0.93
_____ "X" Left	-0.86	1.00	-4.00	0.44	0.68
_____ "Z" Right	-1.29	0.50	-2.50	0.44	0.67
_____ "Z" Left	-1.04	0.50	-2.50	0.73	0.87
_____ ABS "Y"	0.43	1.40	-1.20	0.29	0.55

TABLE VII

Intraoperator Reliability

Statistical Evaluation - Critical Values of t

	t Value	Probability
Operator 1 - Operator 1 PC		
(30 days difference)		
X Right	0.00	$P \leq 0.01$
X Left	0.00	$P \leq 0.01$
Z Right	0.00	$P \leq 0.01$
Z Left	0.00	$P \leq 0.01$
Y	0.00	$P \leq 0.01$
Operator 1 - Operator 1 LG		
(30 days difference)		
X Right	1.00	$P \leq 0.01$
X Left	1.00	$P \leq 0.01$
Z Right	0.00	$P \leq 0.01$
Z Left	1.00	$P \leq 0.01$
Y	1.00	$P \leq 0.01$
Operator 2 - Operator 2 PC		
(30 days difference)		
X Right	0.00	$P \leq 0.01$
X Left	0.00	$P \leq 0.01$
Z Right	0.00	$P \leq 0.01$
Z Left	0.00	$P \leq 0.01$
Y	0.00	$P \leq 0.01$
Operator 2 - Operator 2 LG		
(30 days difference)		
X Right	0.45	$P \leq 0.01$
X Left	0.38	$P \leq 0.01$
Z Right	1.94	$P \leq 0.01$
Z Left	1.94	$P \leq 0.01$
Y	1.03	$P \leq 0.01$

LG = leaf gauge technique PC = power centric technique

TABLE VIII

Interoperator Reliability

Statistical Evaluation - Critical Values of t

	t Value	Probability
Operator 1 - Operator 2 PC		
X Right	1.02	$P \leq 0.01$
X Left	-0.08	$P \leq 0.01$
Z Right	-0.07	$P \leq 0.01$
Z Left	1.95	$P \leq 0.01$
Y	0.88	$P \leq 0.01$
Operator 1 - Operator 2 LG		
X Right	0.17	$P \leq 0.01$
X Left	0.80	$P \leq 0.01$
Z Right	1.25	$P \leq 0.01$
Z Left	1.60	$P \leq 0.01$
Y	2.09	$P \leq 0.01$

TABLE IX

Intertechnique Reliability

Statistical Evaluation - Critical Values of t

	t Value	Probability
Operator 1 PC - Operator 2 LG		
X Right	0.57	$P \leq 0.01$
X Left	0.42	$P \leq 0.01$
Z Right	0.00	$P \leq 0.01$
Z Left	0.42	$P \leq 0.01$
Y	1.60	$P \leq 0.01$

LG = leaf gauge technique PC = power centric technique

CHAPTER V

Discussion

A. General Considerations - Clinical Evaluation

Several clinical observations were made concerning the two bite registration techniques tested. There were advantages and disadvantages associated with each technique along with sublties concerning their successful usage.

In using the leaf gauge technique, it was apparent the subjects either mastered the technique quickly or had difficulty with the procedure for various reasons. Increased amount of muscle tissue development, lack of muscle tissue definition or lack of muscle coordination may have prevented temporalis muscle contraction and masseter muscle relaxation from occurring simultaneously. A few subjects had problems determining the strength in which to bite after they were instructed to bite half hard (moderate pressure). In these subjects muscle fatigue and pain developed.

The majority of subjects had no problems learning to use the leaf gauge correctly. The subjects deprogrammed their musculature and masseter function decreased. If posterior teeth came into contact it was more difficult

to eliminate masseter contraction. Extra leaves were added and the subject was asked to continue the procedure until only temporalis function occurred and no posterior teeth (usually second molars or first premolars) contacted. The tendency for tooth contact during the deprogramming phase may have indicated a continued superior movement of the condyles due to the function of the temporalis and superior head of the lateral pterygoid muscles.

Although no subjects in this study fell into the following categories, it was apparent that the leaf gauge technique would not work well with certain occlusions. In extreme open bite subjects, the separation between the anterior teeth would lead to the use of too many leaves. This could cause a pivotal point on the incisors during deprogramming and lead to one condyle seating more or less than the other. In subjects with an end to end incisor relationship or Class III malocclusion, the incisor relationship was reversed making the correct use of the leaf gauge impossible. The leaf gauge would cause the distraction or posterior displacement of the condyles from the fossa. In this type of patient, it would be best to use a wax interocclusal technique.

After using the leaf gauge to deprogram the musculature and seat the condyles, it was important to ensure that the width of the bite fork holding the formulator mesh was extended past the buccal surfaces of the posterior teeth during the zinc oxide eugenol bite registration. Any contact with

posterior teeth tended to cause the contraction of masseter muscles. This was contraindicated because it would interfere with the superior head of the lateral pterygoid muscles and temporalis muscles ability to seat the condyles in an antero-superior position. Several subjects also disliked the zinc oxide eugenol paste because of the bad taste and the irritation to the intraoral soft tissues and lips.

Subjects were more compliant with the "Two-piece Power Centric delar wax technique". The wax had no taste and left no unpleasant sensations in the oral cavity after it was removed. It was easier to use and required less time to perform the required number of bite registrations. A few subjects had trouble relaxing their mandible during the manipulation phase of the "Power Centric" wax technique. They tried to protrude their mandible into an end to end incisor relationship. This caused the condyles to leave the hinged arc of closure when the anterior wax bite was taken. The majority of subjects had no problem with the wax technique. They voiced a positive experience because zinc oxide eugenol was not used and they did not have to learn how to use a leaf gauge. Coordinating the palpation of temporalis muscle contraction and masseter muscle inactivity was sometimes difficult and frustrating. Overall the wax technique was cleaner and faster and would probably be more effective in children due to compliance.

During the "Power Centric" wax technique, it was important not to alter the consistency of the wax, since it can effect the proprioception of the subject. The wax should be heated to 135 degrees F. and used quickly after removal from the water bath. If the wax is too soft, the required amount of temporalis muscle contraction on the part of the subject was not generated during the anterior registration and the condyles did not seat properly. If the wax was too hard, masseter function would increase and cause the distraction of the condyles from their seated position.

The two pieces of wax used in the "Power Centric" technique needed to be trimmed to fit each individual's mouth. Any excess wax, especially in the posterior section effected the accuracy of the bite registration by impinging on the cheek. This caused some posterior wax bites to warp in the mouth before being cooled and prevented them from fitting on the models. Complete cooling was important and waiting for the wax to harden was a drawback of the technique just as waiting for the zinc oxide eugenol to set during the leaf gauge technique.

B. Findings - Intra-operator reliability

Intra-operator reliability was evaluated by taking three bite registrations at each appointment for each technique and by using the split cast technique to compare the interocclusal records. The split cast technique

originated by Needles (1923), used by Lauritzen (1964) and illustrated by Gugino (1984) was a simple method for checking centric relation bite registrations and testing repeatability. "The best way to check a centric relation record is to secure two or more identical records." (Lucia, 1964) When two out of three occlusal registrations matched, a reproducible seated condylar position was assumed.

During this study, there were only two times that two of three interocclusal registrations did not match. Operator two was performing techniques at both those times; subject 10 during the leaf gauge technique and subject 24 during the power centric technique. It was interesting to note that neither subject had trouble with either technique when operator one was performing them. Also, both subjects had at least two of three registrations match at a different time with operator two for each technique. Subject 10 had all three registrations match thirty days later using the leaf gauge with operator two. This subject had trouble learning how to use the leaf gauge initially as discussed in the clinical evaluation section. Subject 25 was present on the day when the temperature of the water bath exceeded 135 degrees Fahrenheit. Two of three wax registrations were distorted. After adjusting the temperature, the third registration matched the previous mounting thirty days before. Despite the two times that two of three occlusal registrations did not match, it was clearly evident that both techniques were consistently

reproducible for both operators.

This study also tested intra-operator reliability thirty days after the first set of registrations were taken. The second set of registrations were checked on the original mounting (for operator and technique) and the number of matched registrations were tabulated. If none of the registrations matched the previous bite registrations, a second mounting was done to test repeatability on that set of registrations. These registrations are denoted by an asterisk in Tables I and II. A second mounting was needed for subject 2 operator 1 and subjects 1, 3, 4, 5, and 21 operator 2 during the leaf gauge technique. It was not necessary for any of the subjects casts to be remounted for the power centric technique. This suggests that the leaf gauge technique was less reliable over time than the power centric technique. This was probably due to the technique's dependency on the subject to use the leaf gauge accurately. (Bilateral temporalis contraction with little or no bilateral masseter contraction.)

Table VII represents a statistical evaluation of intra-operator reliability thirty days apart for each technique. A paired t-test was performed for each raw data measurement (X right, X left, Z right, Z left, Y) to ascertain whether there was a statistically significant difference between each technique over two different points in time. There was no statistically significant difference for any measurement for operator or technique ($p \leq 0.01$). Even

though there was no difference, it was evident from the calculated t values that there was less intra-operator reliability using the leaf gauge technique as compared to the power centric technique. This was due to the cases which needed to be remounted a second time as seen in Tables I and II. These cases accounted for any t values other than 0.00 because the raw data measurements differed thirty days later.

The statistical analysis for the leaf gauge technique and power centric technique both confirmed Celenza's (1973) work. He found that in four of five subjects who were tested over a 21 day period at one week intervals, there did not seem to be any influence of time on consistency or repeatability of centric relation. This contrasts with the work of Grasso and Sharry (1968) who found significant changes in the variability of the apex position (centric relation position) of the needlepoint tracings during one day and over a 29-day period. Lucia stated frequently, especially after prolonged investigation with a pantographic apparatus on a patient, the posterior styli on the vertical plates were seen to be below the centric position while the anterior styli "appeared" to be at the apex. This indicated condylar drop and would have to result in an anterior rotation outward. If one condyle dropped more than the other, there would be a resulting mediolateral movement in addition to the anteroposterior displacement of the apex point. This could in part account for the variability of the apex position over a 29-

day period as reported by Grasso and Sharry.

Gysi (1910) demonstrated the desirability of the arrow-point tracing in indicating the centric position in edentulous subjects. He pointed out, however, the sagittal tracings were inconsistent and therefore of no value and implied that joint movements could not be repeated. McCollum, Stallard, and Stuart, however, pointed out Gysi's apparatus was not stable and this influenced his findings. They constructed an apparatus which was stable and reported consistent tracings. They concluded the joint pathways were repeatable and centric relation was a reliable position to reconstruct dentitions.

It was important to note the previous mentioned studies used different techniques to obtain centric relation registrations. They were not using the leaf gauge technique or the power centric technique nor were they using the same quantitative instruments to collect the raw data measurements of "X", "Z" and "Y". The present study used the Mandibular Position Indicator (M.P.I.) to quantify the condylar position while the previous studies mentioned used a pantographic apparatus. This eliminated the patient variable and truly tested operator technique during recording of condylar position since the M.P.I. was used on the articulator and the pantograph was used on the patient. The data collected in this study served to defuse the controversy of the previously mentioned literature and bridge the past

techniques and armamentarium with the present. It suggests with these two bite registration techniques and a standardized method of recording condylar position, centric relation was a stable and reproducible position over time. Therefore, it could be used to monitor orthodontic progress, repositioning splint therapy or full mouth reconstruction.

As illustrated in this paper, the mounting of pretreatment models and quantitatively monitoring the progress position of the condyles through the use of centric relation bite registrations could be a simple but extremely informative addition to the practitioner's treatment regimen. It could be used to 1) evaluate pre-treatment centric relation - centric occlusion discrepancies, 2) aid in treatment planning dysfunctional patients, 3) aid in documenting stable condylar position following splint therapy, 4) evaluate tooth positions and arch coordination before removing orthodontic appliances, and 5) evaluate for equilibration procedures.

C. Findings - Inter-Operator Reliability

Inter-operator reliability was evaluated by performing paired t-tests on each measurement for each technique. Table VIII represents a statistical evaluation of inter-operator reliability. There was no statistically significant difference between the two operators for any measurement utilizing each technique ($p \leq 0.01$).

Only two previously mentioned studies used two operators to collect occlusal registrations. Neither of them studied inter-operator reliability. Kantor (1973) studied replicability of intermaxillary records utilizing four different techniques. In an effort to examine intra-operator variability during the study, two additional subjects were tested by a second operator. Results obtained produced graphic tracings of the same character as those produced on the initial fifteen subjects that the first operator tested. No statistical analysis was done. Levinson (1982) used two different operators to compare two different techniques, bilateral manipulation and an anterior biting jig method. One operator was responsible for each technique. Therefore, bias was built into the design of this study and any conclusions which could be drawn from the results; either inter-operator or intertechnique.

The design of the present study enabled a statistical evaluation of inter-operator reliability that no previous study could equal. Two separate operators performed each technique on twenty-eight subjects. They learned these techniques first hand, together, from the respective advocators. This introduced little bias into this study. Before testing for inter-operator reliability, it was important to first test for reproducibility and intra-operator reliability of both techniques. This indicated a high degree of inter-operator reliability that has important implications. First, the techniques were easily taught and learned making it possible for them to become standardized

techniques used throughout the dental community. Second, this would raise the level of standard of care for all dental disciplines.

D. Findings - Intertechnique

Since no statistically significant differences were found between the techniques thirty days apart or between the two operators for each respective technique, a paired t test was performed between operator one's power centric measurements and operator two's leaf gauge measurements to test intertechnique reliability. Table IX represents a statistical evaluation of intertechnique reliability. No statistically significant difference was found to exist for the group of measurements between the two operators irrespective of these two techniques ($p \leq 0.01$). The significance of the above statement lies in the fact two different individuals could be trained by two different clinicians and perform their respective techniques equally. Equally significant, the two techniques rely on different mechanisms; one operator guided and the other muscle determined. This was an interesting finding since controversy existed as to what was the controlling factor in centric relation position. Aprile and Saizar (1947) expressed the opinion the ligaments and capsules of the temporomandibular joints were the positioners of the mandible. Posselt (1952) stated mandibular border positional movements were controlled by the ligaments. Sears (1952) postulated the soft tissues

posterior to the ramus were also a controlling factor of mandibular position. Boucher (1961) claimed the muscles determine the extent of border movements. Moses (1962) had not accepted fixed points of reference on soft tissues as lifelong factors in the registration of mandibular positions. McMillen (1972) concluded from his findings that muscles, ligaments, and bony structures might all be factors in limiting mandibular movement.

From the present study, no direct conclusions could be drawn as to the limiting anatomical structures and physiologic constraints of a centric relation position. It may, however, be extrapolated, since the leaf gauge technique was primarily a muscle determined position and the power centric technique was operator guided with the primary anatomical restrictions of muscles, ligaments, and bone, that McMillen's statements were possibly confirmed. Centric relation position had an individualized range of an acceptable position that was governed by that particular patient's anatomical and physiologic make-up. The resting state of the individual may alter that range for any given time and that the reproducibility for that patient was dependent upon several factors. It must be assumed that no pathology was present in the stomatognathic system that would change spatial relationships. Also, the range was small enough that neither technique was sensitive enough to reflect small changes in a rather narrow physiological range that would be statistically significant or clinically important. If any of the suppositions were

in effect then it would be hard to confirm or deny McMillen's work but there would be a tendency to support it in a normal population.

E. Other Centric Relation Recording Procedures

Although there were no presently known studies which compare either the leaf gauge or power centric techniques to other accepted centric relation registration procedures, several techniques have been compared and cited in the literature review. In past studies, several techniques were reported as being repeatable. Strohaver (1972) found utilizing a Lucia jig with zinc oxide eugenol registration material produced interocclusal records which were similar in one subject. Celenza (1973) found the guided biting point method was duplicable for one operator with fifteen subjects. Kantor (1973) found bilateral manipulation as advocated by Dawson (1974) was most replicable in fifteen subjects with one operator. Simon and Nicholls (1980) found bilateral manipulation and chin point guidance with an anterior jig to be repeatable in five female subjects within a small range of mandibular positions. Levinson (1982) compared the anterior biting jig method with bilateral manipulation in four subjects. He found the anterior biting jig method was the most reproducible although a different operator performed each technique. Lee (1987) found bilateral manipulation was more reproducible than chin point guidance with a Lucia jig or the Myo-Monitor.

The present study and the previous studies suggest several techniques are capable of registering a reproducible centric relation position.

In future studies where techniques are found to be repeatable, condylar position using the reference point centric occlusion should be evaluated. In the present study, the average horizontal ("X") change from centric occlusion to centric relation was 0.54 millimeters. The average vertical ("Z") change was 1.10 millimeters. This average deflection was similar to data supplied by Dr. Wong (1986) on 199 pre-treatment orthodontic patients. His measurements were obtained using the power centric technique ("X" - 0.75; "Z" - 1.45). Williamson (1978) found, in a sample of 18 Angle Class I and 23 Angle Class II patients, the average horizontal difference between centric relation and centric occlusion was 0.35 mm. In Class II patients, the range was 0 to 4 mm, and five patients had an anterior slide of 2.5 mm or greater. In Class I patients, the range was 0 to 2.5 mm. Only two of the 18 patients displayed anterior slide of 2.5 mm or more. In Class II patients, the condyles also were situated an average of 1.37 mm more superiorly in centric relation than they were in centric occlusion. Seven patients had condyles that seated at least 3 mm more superiorly, and one patient showed a difference of 5 mm. In Class I patients, the condyles were seated an average of 1.02 mm more superiorly in centric relation, with a range of 0 to 2.5 mm. One can conclude, therefore, in a normal Class I

patient the average horizontal condylar deflection from centric occlusion to centric relation was approximately 0.5 mm posterior and 1.0 mm vertical. In Class II patients, the amount of vertical condylar distraction may be significant. Since patients with large vertical distractions had centric relation - centric occlusion discrepancies which were hard to detect clinically, it would be prudent to mount all pre-treatment diagnostic models and formulate treatment plans accordingly. For these reasons, mounting models for review of progress during antero-posterior orthopedic correction would also be helpful. During the finishing stages of orthodontic treatment, inspection of mounted models could also allow the orthodontist to detect tooth positions or arch coordination which need to be corrected.

Several centric relation recording procedures which were found to be repeatable could be evaluated using the average deflections. Future studies could answer the question of which technique would be best for seating the condyles in centric relation for the cases which have a large vertical distraction. This may indicate whether the leaf gauge technique or the power centric technique was more sensitive to patients who do not have normal occlusions.

Also, future studies may be designed to incorporate dysfunctional patients whose underlying anatomic and physiologic relationships are unstable, parafunctional, or pathologic in nature. While both techniques

were highly reproducible in a normal population, this may not be assumed in patients who have malocclusions, dysfunctional mandibular movements and environmental stressors that can affect condylar position.

CHAPTER VI

Summary and Conclusions

The purpose of this investigation was to compare two techniques for obtaining centric relation records. The leaf gauge technique and power centric technique were clinically tested for repeatability and statistically tested for intra-operator reliability, inter-operator reliability, and inter-technique reliability. Since both techniques were advocated by leaders in the orthodontic community, both operators involved in the study traveled to the respective offices to learn the procedures first hand.

The sample consisted of twenty-eight dental and hygiene students. There were fifteen males and thirteen females with an average age of 23.3 years old. The main criterion for selecting patients was the absence of signs and symptoms of mandibular dysfunction. Two independent operators were used to perform the mandibular recording techniques. The SAM system (Great Lakes Orthodontics) was used for collecting the raw data and analyzing replicability. Paired t-tests were used to compare intra-operator, reliability, inter-operator reliability and inter-technique reliability.

The following conclusions were drawn from this investigation.

1) Both techniques were consistently reproducible for both operators.

2) No statistically significant difference was found for any measurement (X right, X left, Z right, Z left, Y) between each technique used at two different points in time. It was evident from the calculated t values the leaf gauge technique might be less reliable when compared to the power centric technique.

3) No statistically significant difference was found between the two operators for any measurement utilizing each technique.

4) No statistically significant difference was found to exist for any measurement between the two operators irrespective of these two techniques.

Therefore, either operator could perform either technique and obtain equally consistent interocclusal records for diagnosis and treatment planning.

The use of study models that are mounted on an articulator with an appropriate centric relation interocclusal record are providing very interesting insights regarding occlusion and condylar position. While considerable information can be gained through the visual observation of models mounted on an articulator, additional information can be provided by new instrumentation that quantifies the difference in the position of the mandible when it is in centric relation and centric occlusion. The difference in condylar position can be surprising and in many cases, alter a treatment plan.

The routine use of models mounted in centric relation indicates while many patients have a very close relationship between centric relation and centric occlusion, a significant percentage of patients have a large centric relation - centric occlusion discrepancy (vertical distraction) that cannot be detected during a clinical examination. Future studies should be done on samples of subjects with large vertical distractions and subjects who present with severe malocclusions. These samples would have more variable condylar positions than the sample used in this study. This may define which technique is more sensitive to large discrepancies in centric relation - centric occlusion and the corresponding relationship of severe malocclusions. It could also indicate which technique produces a more reproducible physiologic position for treatment planning orthodontics or occlusal rehabilitation for these particular groups of patients.

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APPENDIX A

LOYOLA UNIVERSITY MEDICAL CENTER
Maywood, Illinois

Orthodontic Department

INFORMED CONSENT

Patient's Name: _____
Date: _____

Project Title: A COMPARATIVE STUDY OF TWO TECHNIQUES USED FOR DETERMINING THE SEATED CONDYLAR POSITION IN HUMAN SUBJECTS.

PATIENT INFORMATION

1. Description and explanation of procedure for Dental Students.

   The purpose of this study is to compare two widely used clinical techniques of obtaining a pretreatment jaw relationship. This is similar to having dental impressions taken with the jaw joint correctly positioned. One technique is determined by the muscles of the individual using a leaf gauge to reprogram the bite. The second technique is obtained by having the investigator guide the jaw to the correct position. These procedures may cause minor discomfort to the ears plus possible tenderness to the facial region. Approximately 5 one-hour appointments will be required. During the appointments, standard dental impressions and records (facebow transfer) of each individual will be recorded. All materials and techniques used in this study are commonly used in orthodontic offices on patients about to undergo orthodontic treatment. We are trying to better understand the jaw joint position in order to improve the diagnosis and subsequent treatment of malocclusions.

2. Risks and discomforts:

   The only risks involved in this research are minimal and equivalent to those of routine dental (impressions) procedures.

   1. Gagging or swallowing the impression material.
   2. Minor discomfort to the ears during facebow transfer.
   3. Temporary tenderness in the facial muscles following leaf gauge therapy.

It is understood that biomedical or behavioral research such as that in which you have agreed to participate, by its nature, involves risk of injury. In the event of physical injury resulting from these research procedures, emergency medical treatment will be provided at no cost, in accordance with the policy of Loyola University Medical Center. No additional free medical treatment or compensation will be provided except as required by Illinois law. In the event you believe that you have suffered any physical injury as a result of participation in the research program, please contact Dr. Robert E. Henkin, Chairman, Institutional Review Board for Protection of Human Subjects at the Medical Center, telephone (312) 531-3777.

3. Potential Benefits:

The direct benefit to the patients in this study will be a complete clinical centric relation - centric occlusion evaluation at no charge. The benefit to future patients would be advancements in the diagnosis and treatment of dental malocclusions and temporomandibular joint disorders.

4. Confidentiality:

I agree to allow my name and medical records to be available to other physicians and researchers for the purpose of evaluating the results of this study. I consent to the publication of any data which may result from these investigations for the purpose of advancing medical knowledge, providing my name or my child's name or any other identifying information (initials, social security number, etc.) is not used in conjunction with such publication.

All precautions to maintain the confidentiality of medical records will be taken.

5. Alternatives:

This study does not include patients care or treatment. The alternative to consent is non-participation in the study.

6. Financial Risks:

The participants of this study will not assume any financial responsibility for the procedures performed during the course of the study.

CONSENT

I have fully explained to _____ the nature and purpose of the above-described procedure and the risks that are involved in its performance. I have answered and will answer all questions to the best of my ability.

(signature: principal investigator)

I have been fully informed of the above described procedure with its possible benefits and risks. I give permission for my/my child's participation in this study. I know that Dr. Gary Klein or his associates will be available to answer any questions I may have. If, at any time, I feel my questions have not been adequately answered, I may request to speak with a member of the Medical Center Institutional Review Board. I understand that I am free to withdraw this consent and discontinue participation in this project at any time without prejudice to my/my child's medical care. I have received a copy of this informed consent document.

I understand that biomedical research such as that in which I have agreed to participate, by its nature, involves risk of injury. In the event of physical injury resulting from these research procedures, emergency medical treatment will be provided at no cost, in accordance with the policy of Loyola University Medical Center. No additional free medical treatment compensation will be provided except as required by Illinois law.

In the event I believe that I have suffered any physical injury as the result of participation in the research program, I may contact Dr. Robert E. Henkin, Chairman, Institutional Review Board for the Protection of Human Subjects at the Medical Center, telephone (312) 531-3777.

I agree to allow my name and medical records to be available to other authorized physicians and researchers for the purpose of evaluating the results of this study. I consent to the publication of any data which may result from these investigations for the purpose of advancing medical knowledge, providing my name or any other identifying information (initials, social security numbers, etc.) is not used in conjunction with such publication. All precautions to maintain confidentiality of the medical records will be taken. I understand, however, that the Food and Drug Administration of the United States Government is authorized to review the records relating to this project.

(signature: patient/parent/legal representative)

(signature: witness to signature)

Children's Assent to Consent:

I have been fully informed of my disease; the procedure medications and side effects that may occur during my treatment. I give permission to be part of this study. I know that Dr. Gary Klein and/or his associates will be available to answer any questions that I may have. I understand that I am free to withdraw this Assent to Consent and participation at any time. I have received a copy of this Children's Assent to Consent.

_____

(signature: patient/parent/legal representative)

_____

(signature: witness to signature)

APPENDIX B

RAW DATA

Subject #1

Operator 1 - Power Centric

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-0.5
"Z" Left	-0.5
ABS "Y"	0.3

Operator 1 - Leaf Gauge

"X" Right	-0.5
"X" Left	-1.0
"Z" Right	-1.5
"Z" Left	0.0
ABS "Y"	0.3

Operator 2 - Power Centric

"X" Right	-1.5
"X" Left	-1.5
"Z" Right	1.0
"Z" Left	1.0
ABS "Y"	-0.3

Operator 2 - Leaf Gauge

"X" Right	-0.5	*0.0
"X" Left	-1.0	2.0
"Z" Right	-0.5	0.0
"Z" Left	-0.5	-1.5
ABS "Y"	0.8	0.5

* Second reading necessary because no bite registrations matched previous mounting 30 days earlier

Subject #2

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	0.0
"Z" Left	0.0
ABS "Y"	0.3

Operator 1 - Leaf Gauge

"X" Right	0.0	*1.0
"X" Left	-1.0	1.0
"Z" Right	0.0	0.0
"Z" Left	0.0	1.0
ABS "Y"	0.7	0.5

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	-1.0
"Z" Right	0.0
"Z" Left	0.0
ABS "Y"	0.7

Operator 2 - Leaf Gauge

"X" Right	0.0
"X" Left	0.5
"Z" Right	0.0
"Z" Left	0.5
ABS "Y"	0.9

* Second reading necessary because no bite registration matched previous mounting 30 days earlier

Subject #3

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	-0.5
"Z" Right	-1.0
"Z" Left	0.0
ABS "Y"	0.3

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	0.5
"Z" Right	0.0
"Z" Left	-0.5
ABS "Y"	0.5

Operator 2 - Power Centric

"X" Right	1.0
"X" Left	0.5
"Z" Right	-2.0
"Z" Left	-2.0
ABS "Y"	0.3

Operator 2 - Leaf Gauge

"X" Right	0.0	*-0.5
"X" Left	-1.0	0.0
"Z" Right	-1.0	0.0
"Z" Left	-0.5	0.0
ABS "Y"	0.5	0.5

* Second reading necessary because no bite registrations matched previous mounting 30 days earlier.

Subject #4

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-3.0
"Z" Left	-3.0
ABS "Y"	0.1

Operator 1 - Leaf Gauge

"X" Right	-1.5
"X" Left	-2.0
"Z" Right	-1.5
"Z" Left	-1.5
ABS "Y"	0.3

Operator 2 - Power Centric

"X" Right	-1.5
"X" Left	-3.5
"Z" Right	-1.0
"Z" Left	-1.5
ABS "Y"	-0.9

Operator 2 - Leaf Gauge

"X" Right	-1.0	*-1.0
"X" Left	-2.0	-1.0
"Z" Right	-1.5	-5.0
"Z" Left	-1.5	-5.0
ABS "Y"	0.4	-1.0

* Second reading necessary because no bite registrations matched previous mounting 30 days earlier

Subject #5

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.5
"Z" Left	-1.5
ABS "Y"	0.6

Operator 1 - Leaf Gauge

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-0.5
"Z" Left	-1.0
ABS "Y"	0.8

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-2.0
"Z" Left	-2.0
ABS "Y"	-0.4

Operator 2 - Leaf Gauge

"X" Right	-3.0	*-0.5
"X" Left	-0.5	0.0
"Z" Right	-2.5	0.0
"Z" Left	-2.0	-0.5
ABS "Y"	0.2	-0.5

* Second reading necessary because no bite registrations matched previous mounting 30 days earlier

Subject #6

Operator 1 - Power Centric

"X" Right	-0.5
"X" Left	-1.0
"Z" Right	-0.5
"Z" Left	-0.5
ABS "Y"	1.0

Operator 1 - Leaf Gauge

"X" Right	-1.0
"X" Left	1.0
"Z" Right	-1.5
"Z" Left	0.0
ABS "Y"	1.4

Operator 2 - Power Centric

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	1.1

Operator 2 - Leaf Gauge

"X" Right	-0.5
"X" Left	-1.0
"Z" Right	-1.5
"Z" Left	0.0
ABS "Y"	1.0

Subject #7

Operator 1 - Power Centric

"X" Right	1.0
"X" Left	-0.5
"Z" Right	-1.5
"Z" Left	-2.0
ABS "Y"	0.2

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	-1.5
"Z" Right	0.0
"Z" Left	-2.0
ABS "Y"	0.1

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	-1.0
"Z" Right	-0.5
"Z" Left	-1.0
ABS "Y"	0.3

Operator 2 - Leaf Gauge

"X" Right	0.0
"X" Left	-0.5
"Z" Right	-1.5
"Z" Left	-1.5
ABS "Y"	0.3

Subject #8

Operator 1 - Power Centric

"X" Right	0.5
"X" Left	0.5
"Z" Right	-2.0
"Z" Left	-1.0
ABS "Y"	1.3

Operator 1 - Leaf Gauge

"X" Right	0.5
"X" Left	1.0
"Z" Right	-3.5
"Z" Left	-2.0
ABS "Y"	1.7

Operator 2 - Power Centric

"X" Right	-1.0
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	0.0
ABS "Y"	1.0

Operator 2 - Leaf Gauge

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	0.0
ABS "Y"	1.4

Subject #9

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.5
"Z" Left	-1.0
ABS "Y"	0.3

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	-0.5
"Z" Right	-2.0
"Z" Left	-0.5
ABS "Y"	1.0

Operator 2 - Power Centric

"X" Right	-1.0
"X" Left	-0.5
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.2

Operator 2 - Leaf Gauge

"X" Right	-0.5
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	0.0
ABS "Y"	0.5

Subject #10

Operator 1 - Power Centric

"X" Right	-5.0
"X" Left	-1.5
"Z" Right	-4.0
"Z" Left	0.0
ABS "Y"	2.5

Operator 1 - Leaf Gauge

"X" Right	-2.5
"X" Left	-3.5
"Z" Right	-1.5
"Z" Left	2.0
ABS "Y"	1.2

Operator 2 - Power Centric

"X" Right	-2.5
"X" Left	1.0
"Z" Right	-2.0
"Z" Left	-0.5
ABS "Y"	-1.5

Operator 2 - Leaf Gauge

"X" Right	2.0
"X" Left	-4.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	-1.2

Subject #11

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	1.0
"Z" Right	-1.5
"Z" Left	-1.0
ABS "Y"	1.5

Operator 1 - Leaf Gauge

"X" Right	0.5
"X" Left	-0.5
"Z" Right	0.0
"Z" Left	0.0
ABS "Y"	1.4

Operator 2 - Power Centric

"X" Right	-1.0
"X" Left	0.5
"Z" Right	-3.0
"Z" Left	-2.0
ABS "Y"	1.4

Operator 2 - Leaf Gauge

"X" Right	0.0
"X" Left	-0.5
"Z" Right	-1.5
"Z" Left	-1.0
ABS "Y"	1.0

Subject #12

Operator 1 - Power Centric

"X" Right	-5.0
"X" Left	-5.0
"Z" Right	1.5
"Z" Left	1.5
ABS "Y"	1.1

Operator 1 - Leaf Gauge

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-1.5
"Z" Left	-1.5
ABS "Y"	0.4

Operator 2 - Power Centric

"X" Right	-2.0
"X" Left	-3.0
"Z" Right	-2.0
"Z" Left	-2.5
ABS "Y"	0.1

Operator 2 - Leaf Gauge

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-2.5
"Z" Left	-2.0
ABS "Y"	0.4

Subject #13

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	-1.5
"Z" Right	0.0
"Z" Left	0.0
ABS "Y"	0.4

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	1.0
"Z" Right	0.0
"Z" Left	-0.5
ABS "Y"	1.0

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-0.5
ABS "Y"	0.4

Operator 2 - Leaf Gauge

"X" Right	0.5
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	0.0
ABS "Y"	0.0

Subject #14

Operator 1 - Power Centric

"X" Right	1.0
"X" Left	0.0
"Z" Right	-1.5
"Z" Left	-1.5
ABS "Y"	0.9

Operator 1 - Leaf Gauge

"X" Right	1.5
"X" Left	0.0
"Z" Right	-2.0
"Z" Left	-1.0
ABS "Y"	0.6

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-0.5
ABS "Y"	0.4

Operator 2 - Leaf Gauge

"X" Right	0.5
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	0.0
ABS "Y"	0.0

Subject #15

Operator 1 - Power Centric

"X" Right	-1.0
"X" Left	-3.0
"Z" Right	-1.0
"Z" Left	-1.5
ABS "Y"	0.4

Operator 1 - Leaf Gauge

"X" Right	-1.0
"X" Left	-2.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.9

Operator 2 - Power Centric

"X" Right	-0.5
"X" Left	-2.0
"Z" Right	-2.0
"Z" Left	-2.0
ABS "Y"	0.7

Operator 2 - Leaf Gauge

"X" Right	0.0
"X" Left	-2.0
"Z" Right	-1.5
"Z" Left	-2.0
ABS "Y"	0.4

Subject #16

Operator 1 - Power Centric

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.9

Operator 1 - Leaf Gauge

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-1.5
ABS "Y"	0.6

Operator 2 - Power Centric

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-2.0
"Z" Left	-2.0
ABS "Y"	0.9

Operator 2 - Leaf Gauge

"X" Right	-1.5
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.9

Subject #17

Operator 1 - Power Centric

"X" Right	-0.5
"X" Left	-1.5
"Z" Right	-3.5
"Z" Left	-3.5
ABS "Y"	0.8

Operator 1 - Leaf Gauge

"X" Right	-0.5
"X" Left	-1.0
"Z" Right	-2.0
"Z" Left	-1.0
ABS "Y"	1.4

Operator 2 - Power Centric

"X" Right	1.0
"X" Left	1.5
"Z" Right	-3.5
"Z" Left	-3.0
ABS "Y"	0.7

Operator 2 - Leaf Gauge

"X" Right	0.0
"X" Left	0.0
"Z" Right	-2.0
"Z" Left	-2.5
ABS "Y"	0.0

Subject #18

Operator 1 - Power Centric

"X" Right	2.0
"X" Left	-1.5
"Z" Right	-2.5
"Z" Left	-1.0
ABS "Y"	-0.6

Operator 1 - Leaf Gauge

"X" Right	1.0
"X" Left	0.0
"Z" Right	-2.5
"Z" Left	-1.5
ABS "Y"	-0.2

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-2.5
"Z" Left	-2.0
ABS "Y"	0.3

Operator 2 - Leaf Gauge

"X" Right	1.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.3

Subject #19

Operator 1 - Power Centric

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.3

Operator 1 - Leaf Gauge

"X" Right	-1.0
"X" Left	-2.0
"Z" Right	0.0
"Z" Left	0.0
ABS "Y"	0.4

Operator 2 - Power Centric

"X" Right	1.0
"X" Left	-1.0
"Z" Right	0.0
"Z" Left	0.0
ABS "Y"	0.4

Operator 2 - Leaf Gauge

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-2.0
"Z" Left	0.0
ABS "Y"	1.0

Subject #20auge

"X" Right	0.5
"X" Left	0.0
"Z" Right	-1.5
"Z" Left	0.0
ABS "Y"	-0.1

"X" Right	-1.0
"X" Left	-0.5
"Z" Right	-1.5
"Z" Left	0.0
ABS "Y"	1.9

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.1

Operator 2 - Leaf Gauge

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.3

Subject #21

Operator 1 - Power Centric

"X" Right	1.3
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	1.3

Operator 1 - Leaf Gauge

"X" Right	1.0
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	1.1

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	-1.0
"Z" Right	0.0
"Z" Left	-1.0
ABS "Y"	0.9

Operator 2 - Leaf Gauge

"X" Right	0.0	*0.0
"X" Left	0.5	0.0
"Z" Right	-1.5	-1.0
"Z" Left	-1.5	-1.0
ABS "Y"	1.2	1.0

* Second reading necessary because no bite registrations matched previous mounting 30 days earlier

Subject #22

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.5
"Z" Left	-1.5
ABS "Y"	0.6

Operator 1 - Leaf Gauge

"X" Right	-1.0
"X" Left	-1.5
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.6

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.5
"Z" Left	-1.0
ABS "Y"	0.7

Operator 2 - Leaf Gauge

"X" Right	-1.0
"X" Left	-2.5
"Z" Right	0.0
"Z" Left	0.0
ABS "Y"	0.4

Subject #23

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	-0.5
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.7

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	0.0
"Z" Right	0.0
"Z" Left	-1.0
ABS "Y"	1.0

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-0.5
"Z" Left	-1.0
ABS "Y"	0.6

Operator 2 - Leaf Gauge

"X" Right	0.5
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	-1.5
ABS "Y"	0.6

Subject #24

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	0.0
ABS "Y"	0.8

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	-1.0
"Z" Right	1.0
"Z" Left	2.5
ABS "Y"	0.7

Operator 2 - Power Centric

"X" Right	1.0
"X" Left	0.0
"Z" Right	-2.0
"Z" Left	-1.5
ABS "Y"	0.4

Operator 2 - Leaf Gauge

"X" Right	0.0
"X" Left	-1.0
"Z" Right	-1.0
"Z" Left	0.0
ABS "Y"	0.7

Subject #25

Operator 1 - Power Centric

"X" Right	0.5
"X" Left	0.0
"Z" Right	-1.5
"Z" Left	0.0
ABS "Y"	1.1

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	-1.0
"Z" Right	0.0
"Z" Left	0.0
ABS "Y"	0.4

Operator 2 - Power Centric

"X" Right	-1.5
"X" Left	1.0
"Z" Right	1.0
"Z" Left	-0.5
ABS "Y"	1.8

Operator 2 - Leaf Gauge

"X" Right	-1.0
"X" Left	1.0
"Z" Right	-0.5
"Z" Left	-1.5
ABS "Y"	-0.5

Subject #26

Operator 1 - Power Centric

"X" Right	-1.5
"X" Left	-1.5
"Z" Right	-1.0
"Z" Left	-1.0
ABS "Y"	0.9

Operator 1 - Leaf Gauge

"X" Right	-1.0
"X" Left	0.0
"Z" Right	-2.0
"Z" Left	-2.5
ABS "Y"	0.4

Operator 2 - Power Centric

"X" Right	-1.0
"X" Left	-1.0
"Z" Right	-2.0
"Z" Left	-1.0
ABS "Y"	1.2

Operator 2 - Leaf Gauge

"X" Right	-1.0
"X" Left	-1.5
"Z" Right	-2.0
"Z" Left	-2.0
ABS "Y"	0.6

Subject #27

Operator 1 - Power Centric

"X" Right	-0.5
"X" Left	-0.5
"Z" Right	-1.5
"Z" Left	-2.0
ABS "Y"	0.1

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.5
"Z" Left	-1.5
ABS "Y"	0.3

Operator 2 - Power Centric

"X" Right	-0.5
"X" Left	-1.5
"Z" Right	-1.5
"Z" Left	-1.5
ABS "Y"	0.5

Operator 2 - Leaf Gauge

"X" Right	0.0
"X" Left	0.0
"Z" Right	-2.5
"Z" Left	-2.5
ABS "Y"	0.1

Subject #28

Operator 1 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	0.0
"Z" Left	-1.0
ABS "Y"	0.3

Operator 1 - Leaf Gauge

"X" Right	0.0
"X" Left	0.0
"Z" Right	-0.5
"Z" Left	-2.0
ABS "Y"	0.2

Operator 2 - Power Centric

"X" Right	0.0
"X" Left	0.0
"Z" Right	-1.0
"Z" Left	-2.0
ABS "Y"	0.2

Operator 2 - Leaf Gauge

"X" Right	0.5
"X" Left	-1.5
"Z" Right	-0.5
"Z" Left	-1.0
ABS "Y"	0.5

APPROVAL SHEET

The thesis submitted by Gary Todd Klein, D.D.S. has been read and approved by the following committee:

Dr. Lewis Klapper, Director
Associate Professor, Orthodontics, Loyola University of Chicago

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Dr. Richard Lang
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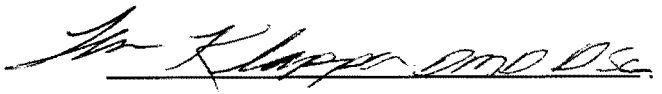
The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

May 30, 1991



Director's Signature