ECCENTRIC TRACTION WITH THE KLOEHN HEADGEAR

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T A B L E   O F   C O N T E N T S

A C K N O W L E D G E M E N T S

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INTRODUCTION

For almost as many years as the Kloehn type extraoral mechanism has been available to the orthodontic profession men have been attempting to alter it's basic design of symmetry in an effort to produce an imbalance of forces delivered to the anchor molar teeth. Depending upon the situation efforts towards this imbalance range anywhere from slightly more force on one anchor molar to one creating almost total unilateral action of the appliance. The original method of offsetting the joint between the outer and inner bows produced variable results depending upon the operator, but did serve to stimulate men, including myself, to investigate the problem more thoroughly. Conflicting opinions regarding the efficacy of unilateral headgears continued to be prevalent as investigators approached the problem by several methods. These may be divided into the categories of clinical impressions, theoretical mechanics, and non-clinical methods utilizing mechanical models. Clinical impressions are certainly valuable but most men require more evidence before they accept them as fact. Theoretical mechanics may be defined as the science which describes and predicts the conditions of rest or motion of bodies under the action of forces. The term "theoretical mechanics" does not mean it is any more theoretical than the mechanics used by engineers or physicists.

The distinction is made in order to separate it from fabrication of appliances, which is sometimes referred to as machanics in the orthodontic literature. Non-clinical methods utilizing mechanical models attempt to duplicate, as nearly as possible, the situation in the mouth and the results are then extrapolated.

It is the purpose of this paper to further investigate and compare the relative efficiencies of the methods of obtaining unilateral action with the Kloehn extraoral mechanism utilizing a mechanical model.

R E V I E W O F T H E L I T E R A T U R E

In January of 1953, J. Philip Baldridge read a paper before the Midwestern Component of the Angle Society entitled "Construction and Use of Unilateral Headcap with Report of Cases".[1] This paper served to create quite a discussion as to whether or not more force was delivered to the anchor molar on the side to which the soldered joint was off-set. At that time he merely presented two cases, (presumably Class II subdivision) in which his unilateral headcap was used, and the models showed the cases in Class I when finished without the use of intermaxillary elastics.

The following January Arthur J. Block gave a report, also to the Midwestern Component of the Angle Society, entitled "An

Analysis of Midline and Offcenter Extraoral Force".[3] Three headgears were constructed possessing identical inner bows of .045 inch stainless steel. The outer bows had their hooked ends on the same horizontal plane with each other and equidistant from symmetrical points on either side of their respective labial arches. The differences between the face bows were the shape of the outer bows and position of attachment of the outer bows to the inner bows. See Fig. 1.

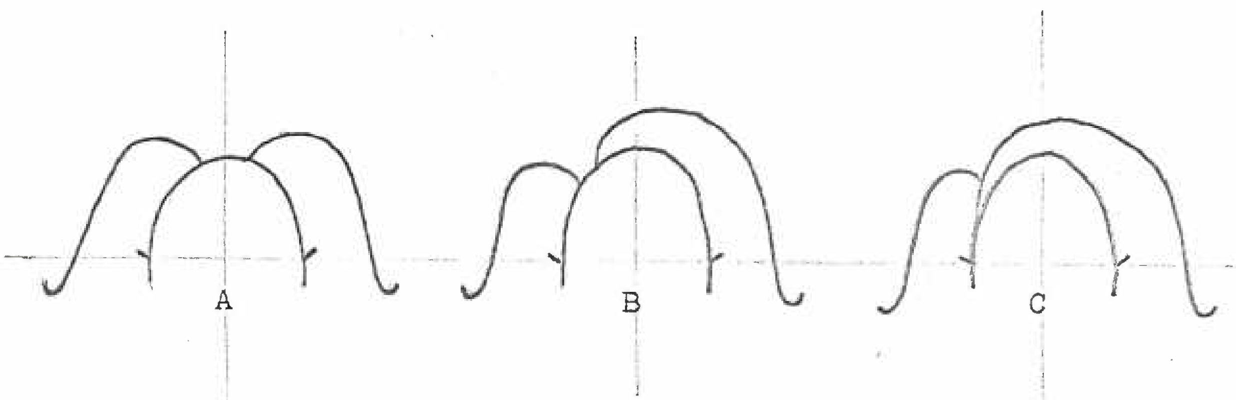

Fig. 1. Types of face bows (Block).

The face bows were placed in a mechanical model and the force was supplied by elastics running from the hooked ends of the outer bows posteriorly to fixed position. To counteract the distal forces and to give an estimate of the reaction force at the anchor molars, elastics were attached to hooks on the inner bows and brought anteriorly to attach to a pair of jackscrews. These jackscrews were then used to increase or decrease the tension in the elastics attached to the inner bows. The final position of the jackscrews, after the face bows were returned to their original positions, indicated an estimate of the relative magnitudes of force delivered to the anchor molars. He found that in the symmetrical situation of Type A the elastic tension was the same on both sides. Type B showed more pull was required to counterbalance the offset side, and with Type C an even greater imbalance between right and left sides was evidenced. He explains his experimental results by drawing an analagy between his headgears and a straight beam containing a load F, and has supports on each end which exert reaction forces R_1 and R_2. According to the physical laws of static bodies : (1) the sum of the forces of any body in equilibrium equals zero; (2) the sum of the moments of any body in equilibrium equals zero. Therefore by moving the applied force F along the beam it is possible to alter relative reaction forces at the supports.

In January, 1955 Vernon R. Bowman[4] presented a paper to the same Society regarding the use of off-center extraoral force. He used elastics and a mechanical base to measure the force at the ends of the inner labial bow. He found that by bending one arm of the outer bow laterally he was able to apply more force to that side. He also had a headgear in which there was a swivel joint attachment between inner and outer bow on one side tubes on the banded first molars, a plastic artificial neck to support the traction strap, and two Dontex stress gauges attached to the inner bow of the headgear just anterior to the buccal tubes. They found their Type A to deliver equal forces to both molars but, in complete disagreement with previous investigators, found their Type B to also deliver equal forces to both molars and termed it a pseudo-eccentric appliance. Their Type C with one outer arm longer than the other was found to be a truly eccentric device and exerted considerably greater force on the side of the longer arm. They explain their results with one of the fundamentals of mechanics which states: "In a statically determinate problem, the internal configuration of a rigid body does not affect the distribution of the external forces on the body." Hence, as long as the attachment of the outer to the inner bow is a rigid one, irrespective of the placement, and the applied forces on the cervical region are symmetrical with respect to the midsagittal plane, the reaction forces on the molars will be the same.

According to Haack and Weinstein the primary consideration in design of an appliance for eccentric cervical traction is one in which the geometry of the angle formed by the ends of the elastic strap tangent to the sides of the neck is such that the bisector of that angle passes closer to the molar on which the greater force is desired. See Fig. 3.

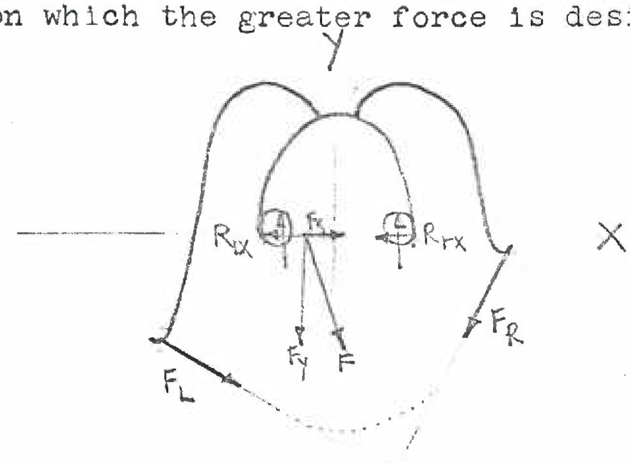

Fig. 3. Force diagram of asymmetrical face bow (Haack & Weinstein).

They point out that the differential in length of arms need not be great to be effective and as the resultant force gets closer and closer to one molar the distal force on the opposite molar diminishes, finally reaching zero or even a negative force as the resultant crosses the X axis buccal to the molar. This, of course, would allow the arm of the inner bow to dislodge from the buccal tube. As the desirable unilateral force is increased, so is the undesirable lateral force. (R_{lx} and R_{rx}) They feel great rigidity is essential and suggest a much heavier face bow consisting of an 0.055 inch inner arch and an 0.075 inch outer bow.

In 1959, E. W. Drenker[5] published a paper discussing the physical mechanics and mathematics involved in unilateral cervical traction. His principles coincide with those presented by Haack and Weinstein in 1958 and he feels that in order to obtain eccentric traction it is necessary to displace the line of action of the resultant of the two external forces of the elastic neck band toward the molar which is to receive greater force. His addition to Haack and Weinstein's method is to move the resultant to one side by moving the outer bows and thereby moving the point of application of the external forces in relation to the midsagittal plane. Since it is impractical to move one of the bows due to the interference provided by the cheek of the patient, all of the shift must come from one side. This is still enough, according to Drenker, to shift the resultant and effectively create an imbalance.

Subsequent work did not convince J. Philip Baldridge that his clinical impressions of the off-set soldered joint headgear, which he discussed in 1953, were wrong. He had tried both lengthening one of the outer arms on the side which was to be moved distally and bending one of the arms laterally, and had experienced clinically that it was more efficient than original one he reported on with the off-set soldered joint. He tested the original off-set type headgear on a patient by placing compressible coil springs on the inner .045 inch bow to which a stop had been soldered to prevent the springs from sliding forward when the arch was placed in the buccal tubes. If unequal force was being exerted at the molars the springs would be of different lengths. He found the springs were not of different lengths and convinced himself that unilateral action cannot be obtained by merely off-setting the solder joint. He also tested the one long arm and widened arm face bows by the same method and his results coincided with the previous workers.[2]

In an article in 1963 on mechanics, Haack[7] discussed the mathematical calculations involved in the one longer arm headgear. He applied actual numerical values to the dimensions and vector quantities to the forces. His calculations showed by lengthening one arm an inch and one-half it was possible to obtain 2.86 times the force on that side. He also calculated the combined lateral force, the individual components of which are statically indeterminate.

MATERIALS AND METHODS

A mechanical model was designed in an effort to test the relative forces delivered to the anchor molar teeth by a symmetrical Kloehn type headgear and four asymmetrical Kloehn types designed for varying degrees of unilateral action. The base of the model consists of 3/16 inch steel, 6 x 8 inches. Two 2 x 2 inch sheets of glass 3/32 inch in thickness were bonded to the top of the base in the posterior one-third to act as a smooth surface relatively free from sliding friction. Centered on the glass surfaces, 2 inches from center to center, rest the simulated molar teeth. These consist of machined cylinders 9/16 inch in diameter at their upper ends and 1/4 inch at their lower ends in order to fit into the inner races of two standard Barden FR-4 bearings. Orthodontic bands were pinched on the upper portions of the cylinders. These bands, to which .045 buccal tubes had been soldered, were then cemented on the cylinders with Eastman cement, care being taken to orient the buccal tubes spatially the same on both. Two 1/8 inch width sections of 3/4 inch pipe posessing an inside diameter of 5/8 inch were cut and four short lengths of .030 wire soldered to them, 90 degrees apart, in the same horizontal plane. The entire cylinder-ball bearing assemblys were pressed into the sections of pipe containing the four soldered wires. These wires were then bent vertically and cut off at the level of the top of the cylinders. Each wire was then grooved at the level of the buccal tubes. To these grooves were tied light nylon thread, capable of supporting several pounds, to be later run over pulleys and attached to weight bearing cups. These 1/2 inch pulleys, mounted on 1/8 inch shafts, were situated on all ends of the base and allowed balancing forces to be applied in all four directions. Between the two simulated molars, two pieces of spring steel were suspended from a split

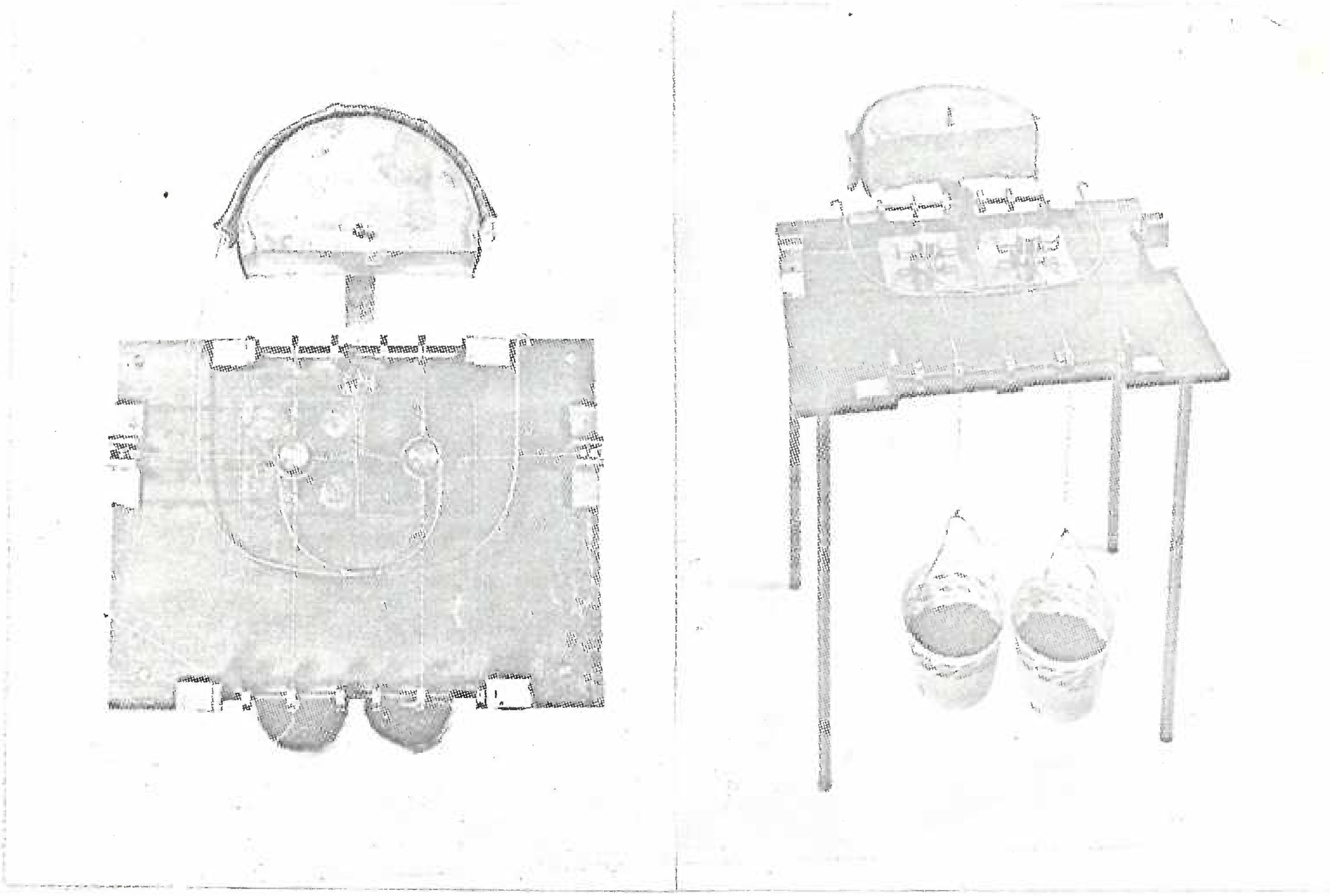

Fig. 4. Mechanical model used to test headgears.

5/16 inch bolt that was bonded to the base. Small holes were drilled in the spring steel at the level of the grooves in the .030 wires to receive the nylon thread which was attached to the bolt by sticky wax. A simulated neck assembly was added to the base by bonding a narrow strip of 3/32 inch steel, containing a vertical 1/8 inch shaft, to the bottom of the base. A four inch diameter neck, free to swivel, was then added to the shaft so that the back of the neck was approximately five and one-half inches posterior to the center of the molars. The base and all its parts were then supported by four permanent steel legs eight and five-eighth inches in length. See Fig. 4.

Five .045 inch steel arch wires for the inner bows of the headgears were adapted to conform to one symmetrical pattern on graph paper so that the ends of the wire would be the same distance apart as the buccal tubes on the model. The outer bows were made of .063 inch wire and were all soldered to the center of the inner bows except in the case of type II as seen in Fig. 5. After soldering, the headgears were completed utilizing graph paper to insure proper relationship between the ends of the inner and outer bows. In the case of types I,II, and III the relationship of the ends of the outer bows to the inner bows were made the same and then the right outer bow of type III was bent laterally until its end was one and one-quarter inches farther from the mid-sagittal plane. Types IV and V were made exactly the same with the right outer arm one and one-half inches longer than the left, and then the right outer arm of the type V was bent laterally so its end was one and one-quarter inches farther from the mid-sagittal plane. Weldable stops were then placed on all inner bows in the same relative positions and reinforced with solder.

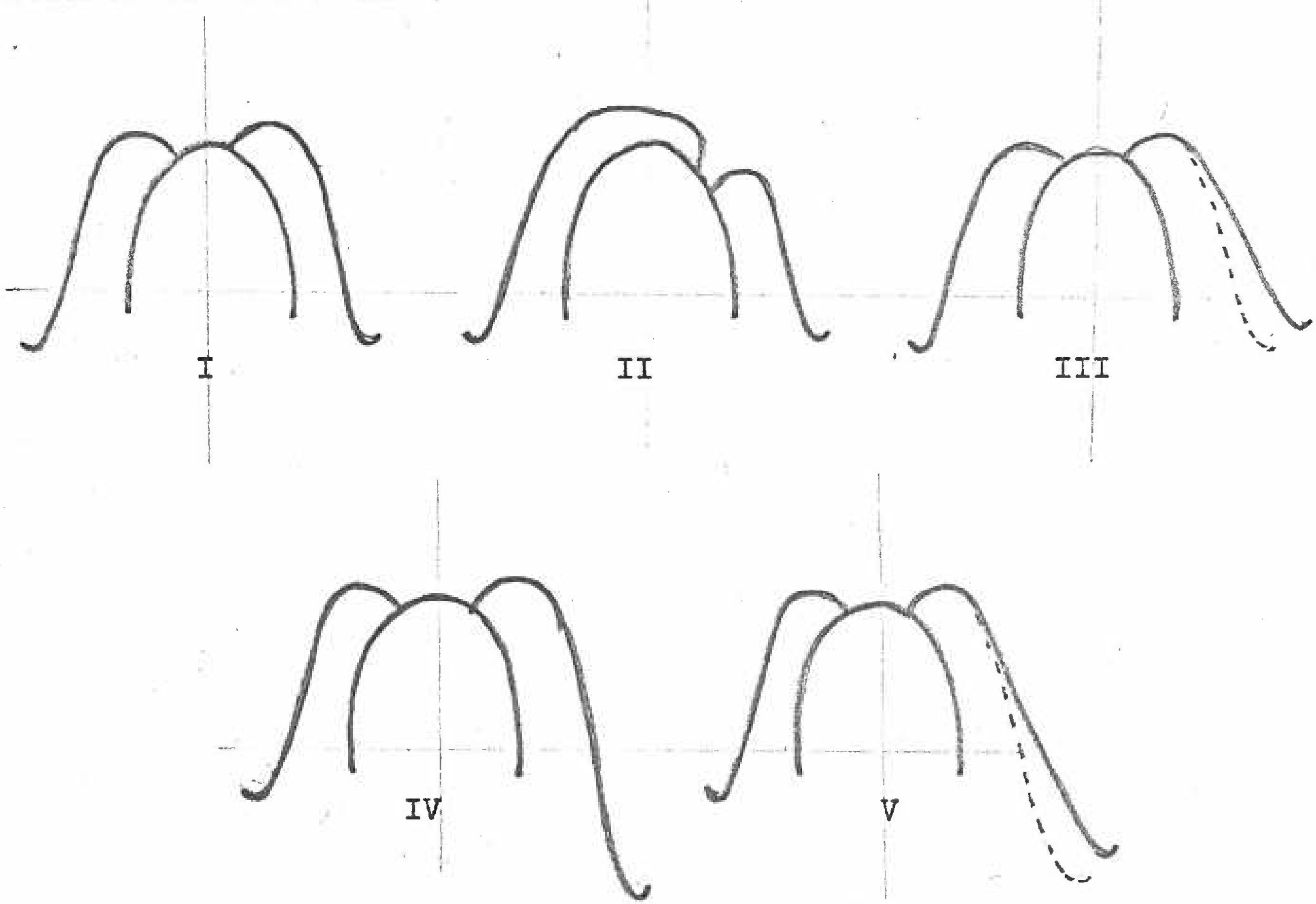

Fig. 5. Designs of face bows tested.

The relative forces provided by each headgear were then measured using the mechanical model. The procedure involved placing a headgear in the buccal tubes, applying traction through the use of varying combinations of elastics from hooks on a Kloehn-Type foam rubber neckband, allowing the cylinder-ball bearing assemblies to displace, and then returning them to their original positions as noted by etchings on the glass. This was accomplished by the addition of weight, in the form of lead shot, to the cups that were attached to the nylon threads. This procedure was repeated ten times for each headgear with a different magnitude of force provided for each measurement by using different elastic combinations ranging from approximately 100 to 1100 grams. The cupfuls of lead shot were then weighed to determine the amounts of force required to return the apparatus to its balance position and thus, the magnitudes of force delivered to the right and left molars. These findings were then plotted right molar against left molar on a composite graph to show the relative efficiencies of the various methods of obtaining eccentric traction.

F I N D I N G S

The values obtained with the Type I, or symmetrical headgear, increased steadily, in the same relative amounts, with

Type	I		II		III		IV		V	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
1.	171.1	153.8	216.1	145.5	253.6	120.6	217.4	155.9	301.4	101.2
2.	203.6	200.9	260.5	188.0	299.4	146.8	248.5	174.2	351.8	115.8
3.	293.6	312.8	288.7	206.2	382.8	206.2	375.4	293.0	510.8	237.9
4.	358.9	334.5	411.1	275.8	566.3	342.2	414.4	332.6	628.9	298.3
5.	403.8	390.2	479.4	315.3	589.6	351.8	531.3	470.0	720.6	411.5
6.	527.6	511.7	663.9	442.0	673.9	398.8	597.5	524.5	736.8	437.1
7.	702.3	677.0	726.1	416.8	690.8	418.2	656.5	573.2	838.2	576.2
8.	784.7	781.9	845.2	543.9	748.5	557.2	740.1	728.6	866.7	546.5
9.	857.0	851.8	905.9	538.4	838.8	579.2	896.0	891.6	894.9	581.7
10.	914.5	927.1	1013.1	598.9	1026.8	746.3	1052.3	1027.3	1078.7	796.7

Table 1. Force values obtained with various headgear designs (grams).

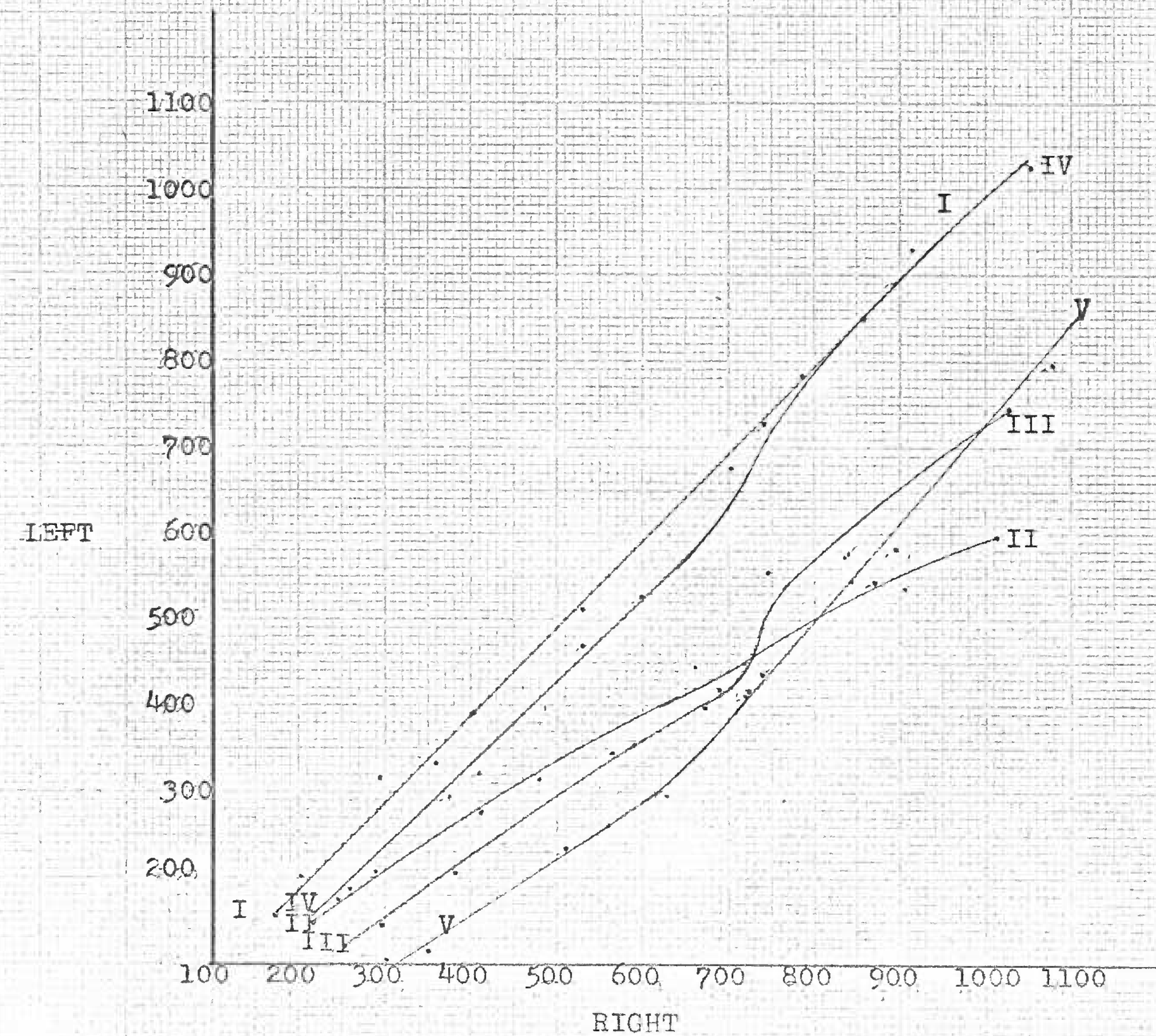

Fig. 6. Composite graph of force values obtained with various headgears. (grams)

increased force application as would be expected. Observation of the graph of figure 6 shows the values to be very close to the theoretical ratio of 1:1 which would be represented by a line at forty-five degrees to the ordinate and abcissa and passing through the origin. The deviation from this theoretical line is an estimate of the error of the method and in this case is quite small.

The Type II headgear, with its off-center soldered joint, provided eccentric traction throughout the entire range of forces. The amount of unilateral action increased linearly with increased force application.

The Type III headgear, which differed from the Type I only because its right outer arm was bent one and one-quarter inches farther from the mid-sagittal plane, was efficient for a good portion of the force range. It's unilateral action also increased linearly with increased force and until the force reached 700 grams on the right molar it was slightly more efficient than the Type II. After this point there was a definite decrease in efficiency and a marked tendency toward bilateral increase.

The Type IV headgear, with the right outer arm one and one-half inches longer than the left, demonstrated poor efficiency for unilateral action. In the low force range it provided a force differential of merely 60 to 70 grams. This differential remained approximately the same until a force of 700 grams was reached on the right molar. The efficiency dropped markedly at this point and above 800 grams it functioned almost perfectly as a symmetrical, bilateral action headgear.

The Type V, which differed from the Type IV only because the right outer arm was bent one and one-quarter inches farther from the mid-sagittal plane, proved to be the most efficient of all designs throughout most of the force range. At the lower end of the range it provided a three to one differential which dropped to two to one somewhere between 600 and 700 grams on the right molar. From this point any increase in force was realized equally on both sides. Above 800 grams on the right molar it became less efficient than the Type II and above 1000 grams it was less efficient than the Type III by a very small amount.

During construction of the various headgears care was taken to provide solder joints which would not allow any expansion of contraction force to be transmitted from the outer to the inner bow upon deformation of the outer arms. This was carefully tested with graph paper and in no instance did a severe expansion or contraction of the outer arms result in a change in width of the inner bow. Width changes were observed, however, during the experiments. All designs showed a definite tendency to widen, particularly above 500 grams. The Type I