The clinical application of a tooth-size analysis

WAYNE A. BOLTON, D.D.S., M.S.D.
Seattle, Wash.

INTRODUCTION

THE present era is one of dramatic progress in the field of clinical orthodontics. This is particularly true with respect to the mechanical phase of our treatments, and of course many of the mechanical advances are dependent upon the development of new materials. Improvements are so numerous that at times it seems as though changes occur almost daily.

Advances in the diagnostic phase of treatment have also been plentiful, particularly with respect to the use of cephalometric headfilms as a pretreatment guide. Most modern investigative endeavors have been along one of these two lines. They seem to have the glamour and appeal to cause one perhaps to ignore one of the most basic of fundamentals—tooth size. The term *tooth size,* in this case, refers specifically to the mesiodistal widths of the teeth.

The development of the tooth-size analysis ratios which are to be the basis of this investigation was presented in 1952.[3] Since that time these ratios have been applied to many clinical orthodontic cases. It is the purpose of this study to review the establishment of the analysis and, from this review, attempt to present practical and detailed examples of the measurement and application of the information derived from the analysis procedures.

It is felt that the tooth ratios can, without difficulty, be made a diagnostic aid which allows the orthodontist to gain insight into the functional and esthetic outcome of a given case without the use of a diagnostic setup.

REVIEW OF THE LITERATURE

G. V. Black[2] conducted one of the first investigations to be made in the field of tooth size. Large numbers of human teeth were measured, and tables of mean figures were established for each tooth in the dental arch.

This thesis, which was given as a partial fulfillment of the requirements for certification by the American Board of Orthodontics, is being published with the consent and the recommendation of the Board, but it should be understood that it does not necessarily represent or express the opinion of the Board.

Lundstrom[6] reviewed the European literature that dealt with tooth size disharmonies. The summary is as follows:

Young (1923) compared two similar occlusions but found that the cases differed considerably in the amount of anterior overbite present. Measurements were taken of the mesiodistal widths of the teeth from the central incisors to the second premolars. The sum of the widths of the maxillary teeth and the sum of the widths of the mandibular teeth were compared. The difference was 10.9 mm. in the case with an edge-to-edge anterior relationship and 17.0 mm. in the case where a deep overbite existed.

The Lux brothers (1930), Ritter (1933), Seipel (1946), and Selmer-Olsen (1949) have studied the maxillary and mandibular tooth widths and their relations. A fairly marked correlation was found to exist between the sum of the widths of the maxillary and mandibular teeth in good occlusion cases.

Tonn (1937) offered a system of ratios between segments of the dental arches. Separate ratios were established for the incisors, $\frac{\text{mandibular}}{\text{maxillary}}$ —.74; the canines, $\frac{\text{mandibular}}{\text{maxillary}}$ —.87; the premolars, $\frac{\text{maxillary}}{\text{mandibular}}$ —.96; the first molars, $\frac{\text{maxillary}}{\text{mandibular}}$ —.92; and the full arches, first molar through the first molar, $\frac{\text{mandibular}}{\text{maxillary}}$ —.93. In each case the smaller value was divided into the larger. Of twenty malocclusion cases which seemed to be characterized by disharmony in tooth size eight had intermaxillary tooth width ratios which fell outside the range.

Korbitz (1940) analyzed 100 normal occlusions. From a comparison in length of the maxillary anterior segment (central and lateral incisors, and canines) to the mandibular segment of central and lateral incisors, canines, and one-half the first premolar width he concluded that the difference should be between 0 and 4.0 mm. and should correspond to an overbite of 0 to 3.5 mm.

Ballard[1] studied asymmetry in tooth size. Five hundred sets of casts were measured. The mesiodistal diameters of each tooth on one side of the dental arch were compared to the corresponding tooth on the opposite side. Ninety per cent of the sample demonstrated a right-left discrepancy in mesiodistal width amounting to 0.25 mm. or more. Ballard advocated the judicious stripping of proximal surfaces, primarily in the anterior segments, when a lack of balance existed.

Neff,[7] with a sample of 200 cases, measured the mesiodistal widths of both the maxillary and mandibular anterior teeth. An "anterior coefficient" was arrived at by dividing the mandibular sum into the maxillary sum. The range was 1.17 to 1.41, with no mean figure given. Neff related the coefficients to the amount of overbite. The value of 1.17 was associated with an edge-to-edge incisor relationship and the opposite extreme, 1.41, was associated with a complete overbite relationship of the incisors. He concluded that a 20 per cent overbite with a coefficient of 1.20 to 1.22 was ideal.

Steadman[8] also offered a method for predetermining the overbite-overjet relationship of the anterior teeth by comparing the width of the maxillary four incisors and one-half the width of the canines to the full mesiodistal dimension of the six mandibular anterior teeth. To compensate for the difference in values, the result of the mandibular arch forming a smaller arc, one-half the thickness of the maxillary central incisor (measured at the incisal third) is subtracted

from the maxillary measurement, and one-half the thickness of the mandibular lateral incisor (measured at the incisal third) is added to the mandibular measurement. If the sums are equal and the canines are in an ideal Class I relationship, a good overbite-overjet relation should result. A value of –2.0 mm. should produce an edge-to-edge incisor relation, while a +2.0 mm. value would indicate a condition of excessive overbite and overjet.

In 1952 I proposed an intermaxillary ratio analysis designed for the purpose of localizing discrepancies in tooth size.[3] Since these ratios form the basis of the present study, a detailed review of their establishment and use will be presented later.

Lundstrom[6] reported an investigation of the variation in intermaxillary tooth-width ratio in an unselected study group consisting of 319 13-year-old children. Measurements of the mesiodistal widths were recorded, and a dispersion was determined for the following three indices:

$$1.\ \frac{I_1 - I_2 - C\ \text{(mandible)}}{I_1 - I_2 - C\ \text{(maxilla)}} \times 100$$

$$2.\ \frac{P_1 - P_2 - M_1\ \text{(maxilla)}}{P_1 - P_2 - M_1\ \text{(mandible)}} \times 100$$

$$3.\ \frac{I_1 - I_2 - \ldots M_1\ \text{(mandible)}}{I_1 - I_2 - \ldots M_1\ \text{(maxilla)}} \times 100$$

Lundstrom concluded that the biologic dispersion in the tooth-width ratio is great enough to have an appreciable influence on the position of the teeth, on tooth alignment, and on the overbite and overjet relationship.

Stifter[9] repeated my study on a similar sample, with comparable results. For the over-all ratio Stifter obtained a mean figure of 91.04 to my 91.3, and for the anterior ratio Stifter's 77.55 figure compared very favorably with my 77.2.

Cooper[5] developed a method for assessing tooth-size disharmonies and localizing the disharmony, if it occurred in the posterior region, by dividing the region into segments and comparing maxillary to mandibular lengths.

In 1958 I published a condensed form of my original tooth-size analysis study, from which ratios and their means were presented.[4] In order to lend background and continuity to the work being offered here, it seems advisable to include the basic portion of the 1958 publication.

MATERIAL AND METHODS

MATERIAL. The measurements used in this study were taken from fifty-five cases in which an excellent occlusion existed. The casts were carefully selected from a large number of excellent occlusions, most of which had been treated orthodontically (nonextraction). Of the fifty-five cases in the sample, forty-four had been treated and eleven were untreated. Selections were made with extreme care.

METHODS. Three-inch needle-pointed dividers were used to determine the greatest mesiodistal diameter of all the teeth on each cast, except for the second

and third molars. The dimensions, to the nearest 0.25 mm., were taken from a finely calibrated millimeter ruler and recorded. The following measurements were made on each set of casts:

1. The mesiodistal widths of twelve maxillary teeth, the right first permanent molar through the left first permanent molar, were totaled and compared to the sum derived from the same procedure carried out on the twelve mandibular teeth. These measurements are shown as X and X′ in Fig. 1. The ratio between the two is the percentage relationship of mandibular arch length to maxillary arch length which we have called the "over-all ratio."

$$\frac{X'}{X} \text{ or } \frac{\text{Sum mandibular 12}}{\text{Sum maxillary 12}} \times 100 = \text{Over-all ratio.}$$

2. The same method was used in setting up a ratio between the maxillary and mandibular anterior teeth. Those measurements are shown as Y and Y′ in Fig. 1. The ratio between the two is the percentage relationship of mandibular anterior width to maxillary anterior width, and this is referred to as the "anterior ratio."

$$\frac{Y'}{Y} \text{ or } \frac{\text{Sum mandibular 6}}{\text{Sum maxillary 6}} \times 100 = \text{Anterior ratio.}$$

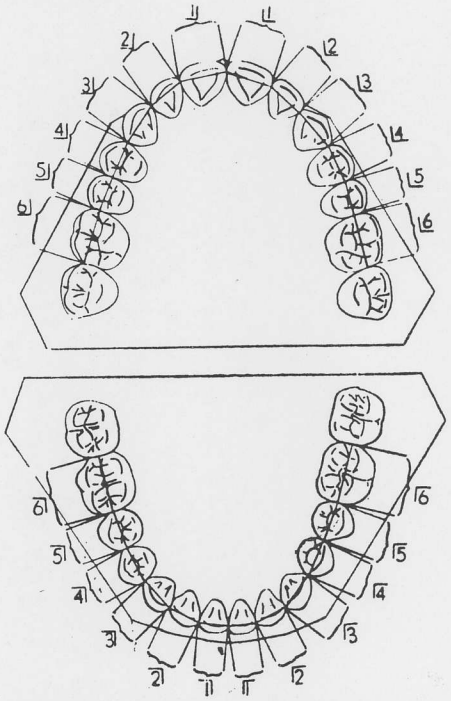

Fig. 1. X is the sum of mesiodistal diameters of maxillary teeth $\underline{654321|123456}$. X′ is the sum of mesiodistal diameters of mandibular teeth $\overline{654321|123456}$. Y is the sum of mesiodistal diameters of maxillary teeth $\underline{321|123}$. Y′ is the sum of mesiodistal diameters of mandibular teeth $\overline{321|123}$.

3. *The angles of the maxillary and mandibular incisors to the occlusal plane were measured.* This was determined by measuring the angles formed by the labial surfaces of the incisors with the base of the cast which was trimmed parallel to the occlusal plane.

STATISTICAL ANALYSIS. The data were judged statistically, and the following abbreviations and formulas of the statistical methods were used:

S.E.M.—Standard error of the mean. This test predicts the degree of variation to be expected in the mean if the experiment were repeated on other similar samples.

S.D.—Standard deviation. This is the constant which measures in absolute terms the degree of scatter or dispersion about the mean.

C.V.—Coefficient of variation. The coefficient of variation relates the standard deviation to the mean by expressing the standard deviation as a percentage of the mean. In order for the standard deviation to be statistically significant in relation to the mean, the coefficient of variation percentage should be small.

C.C.—Coefficient of correlation. This test gives a method of correlating two measurements from the same sample.

FINDINGS

The ratio $\frac{\text{sum mandibular 12}}{\text{sum maxillary 12}} \times 100$ was developed for each individual in the sample, and the analysis shown in Table I was made.

Table I

Range	87.5 - 94.8
Mean	91.3
S.D.	1.91
S.E.M.	0.26
C.V.	2.09%

Similar data were compiled in analyzing the anterior ratio for each individual (Table II), this ratio being $\frac{\text{sum mandibular 6}}{\text{sum maxillary 6}} \times 100$.

Table II

Range	74.5 - 80.4
Mean	77.2
S.D.	1.65
S.E.M.	0.22
C.V.	2.14%

Angles of the labial surfaces of the maxillary and mandibular central incisors to the occlusal plane were taken in order that the axial inclination of the crowns of these teeth to each other might be recorded. The mean was 177.0 degrees.

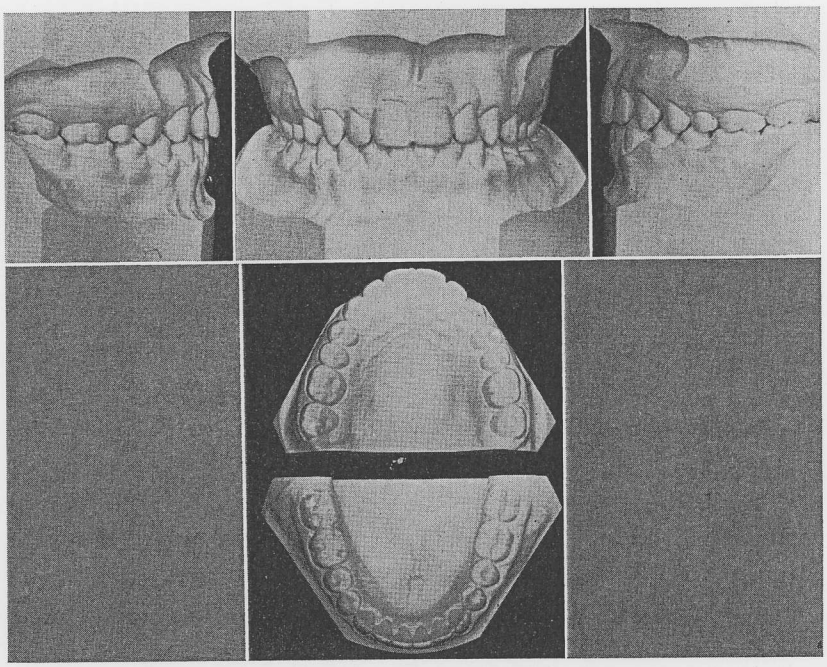

Fig. 2. Models of the untreated "ideal" occlusion used for study and comparison purposes.

DISCUSSION

It was thought that a more satisfactory and significant discussion of the findings could be offered if the presentation were to be developed around actual cases that had been collected for the study. Fig. 2 shows an untreated excellent occlusion. This is the dentition of a 14-year-old girl. There were no restorations or carious lesions. Measurements and ratios recorded from this ideal occlusion were compared with means derived from the complete sample of fifty-five cases. The comparisons are summarized in Table III.

A statistical analysis of both the over-all ratio (Fig. 1, measurements X and X′) and the anterior ratio (Fig. 1, measurements Y and Y′) indicated a small degree of variation in the individual measurements about the mean. In the over-all ratio (Table II) a standard deviation of 1.91 for a mean of 91.3 ±

Table III. *Comparison of an untreated excellent occlusion (Fig. 2) with the mean figures derived from this study*

	Untreated excellent occlusion	*Mean*
Over-all ratio	91.11	91.3
Anterior ratio	77.6	77.2
Overbite	31.2	31.3
Overjet	0.5 mm.	0.74 mm.
Incisor angle	175.5°	177°
Cusp height	2.0 mm.	1.9 mm.

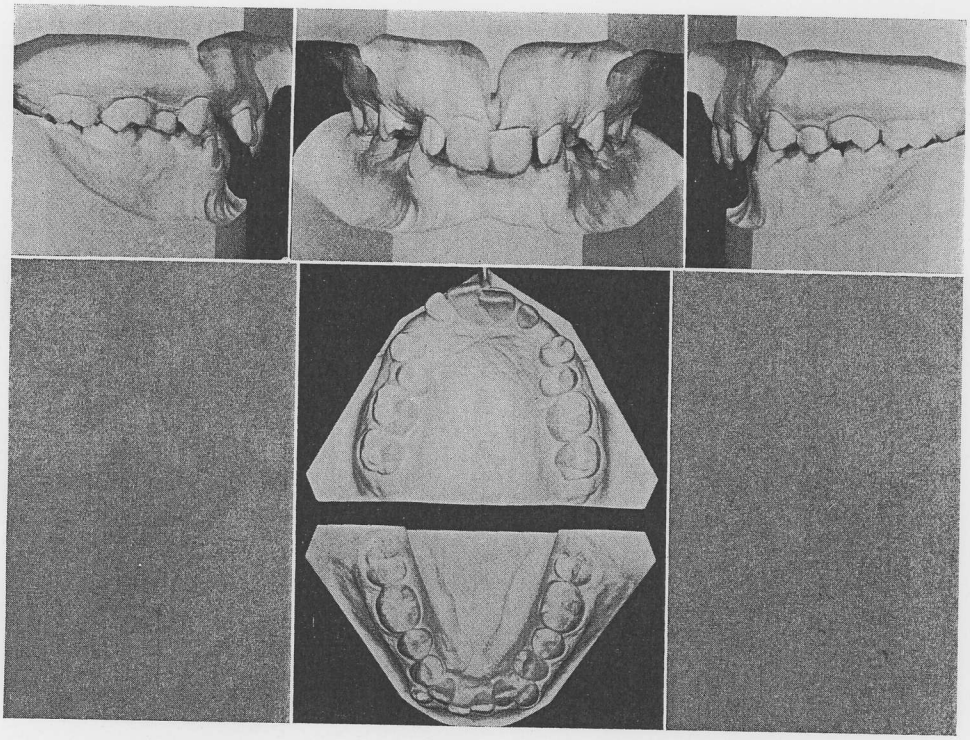

Fig. 3. A malocclusion in which a marked mandibular anterior excess was discovered.

0.26 is very small, as verified by the correspondingly small coefficient of variation, 2.09 per cent. The same pattern held true also for the anterior ratio (Table III). For a mean of 77.2 ± 0.22, the standard deviation of 1.65 is significantly small, as again indicated by the coefficient of variation, 2.14 per cent. Both ratios derived from the case shown in Fig. 2 compare very favorably with the mean figures, as demonstrated in Table III.

The following two cases which presented a marked disharmony in tooth size may help to show the clinical application of the ratios described previously.

Fig. 3 shows four views of a malocclusion in which both the over-all ratio and the anterior ratio were considerably deviated from the means of this investigation. The over-all ratio was 96.46, and the anterior ratio was 86.45. The fact that these figures are larger than their means indicates that the maxillary arch is too small for the existing mandibular arch. The buccal measurements were made, and the resulting ratios were found to be essentially $\frac{1}{1}$. From this, it was suspected that the anterior segments were at fault. This suspicion was borne out by the setup shown in Fig. 4. Interdigitation in the buccal segments was satisfactory, but in the anterior segment the best that could be achieved was an end-to-end relationship which, as shown in the photographs, would be very unsatisfactory.

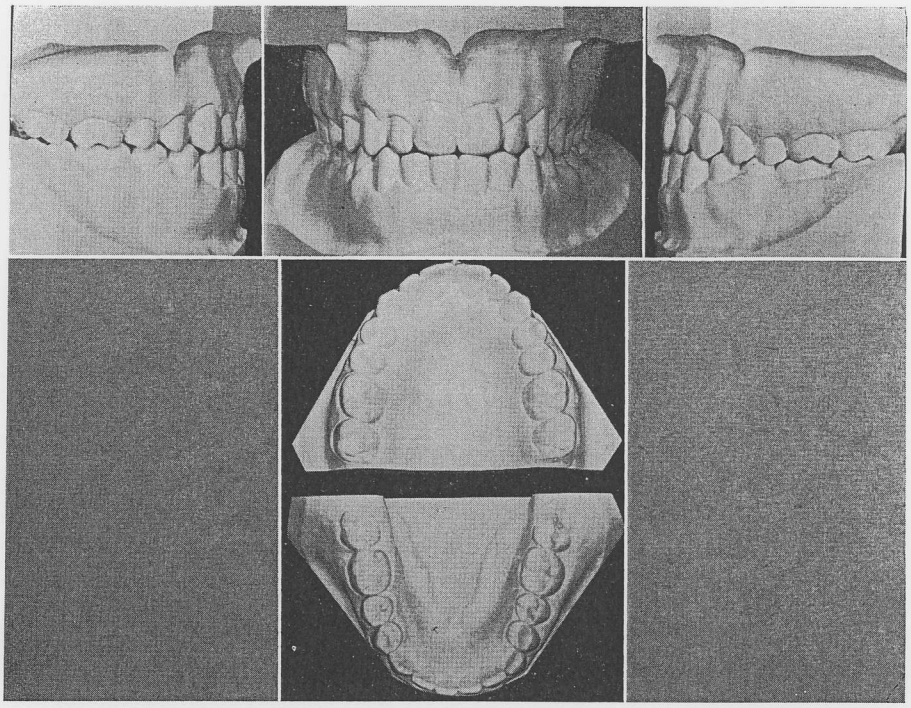

Fig. 4. A setup of the malocclusion shown in Fig. 3, maintaining a full complement of teeth.

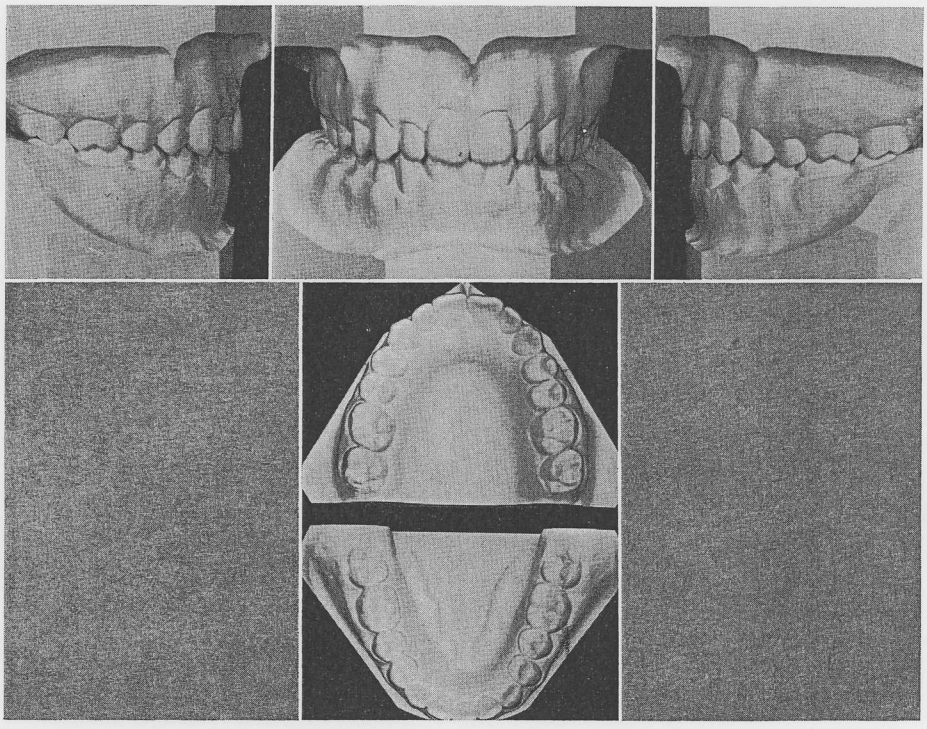

Fig. 5. A setup of the malocclusion shown in Fig. 3, after the removal of one mandibular central incisor.

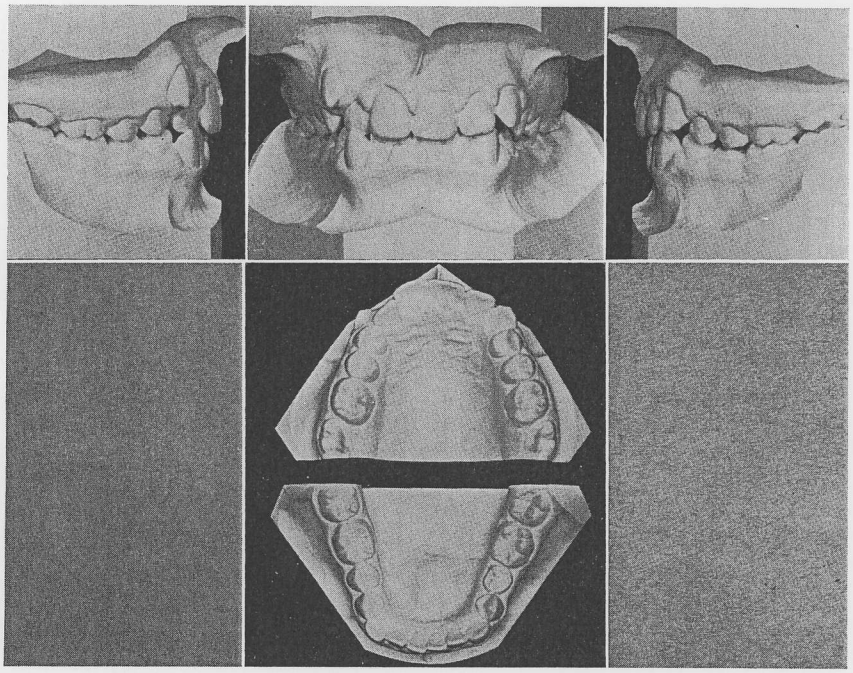

Fig. 6. A malocclusion which contained both an over-all and an anterior discrepancy in tooth size.

By substituting in the anterior ratio formula, $\frac{\text{Sum mandibular 6 (X)}}{\text{Sum maxillary 6 (48)}} \times 100 = 77.2$ (mean), X (the unknown) was found to be 37.05 mm. This is the mesiodistal dimension that the mandibular six anterior teeth should have ideally. Since this unit actually measured 41.5 mm., it was noted that if a satisfactory anterior relationship were to be achieved the mandibular segment should be reduced approximately 4.5 mm. When this reduction was inserted in the over-all formula also, the result was 92.0, within the range of normality, which indicated that the size discrepancy was confined to the anterior teeth.

The removal of 4.5 mm. of tooth structure by stripping the four mandibular incisors and the mesial surface of the canines was considered to be impractical.

The other alternative for reducing this dimension was the extraction of a central incisor whose mesiodistal width was 5.5 mm. The anterior and over-all ratios were then reduced to 75.0 and 91.03, respectively. These readings are slightly below the mean, but the result is demonstrated by the setup shown in Fig. 5. If the mandibular anterior segment were left intact, the final esthetic result would be far from desirable because extreme maxillary anterior spacing would be inevitable, that is, if the buccal segments were in a Class I molar relationship.

The malocclusion shown in Fig. 6 demonstrated a somewhat different type of disharmony, being a case in which the discrepancy in size was not confined to one segment but involved a complete dental arch. The over-all and anterior

Fig. 7.

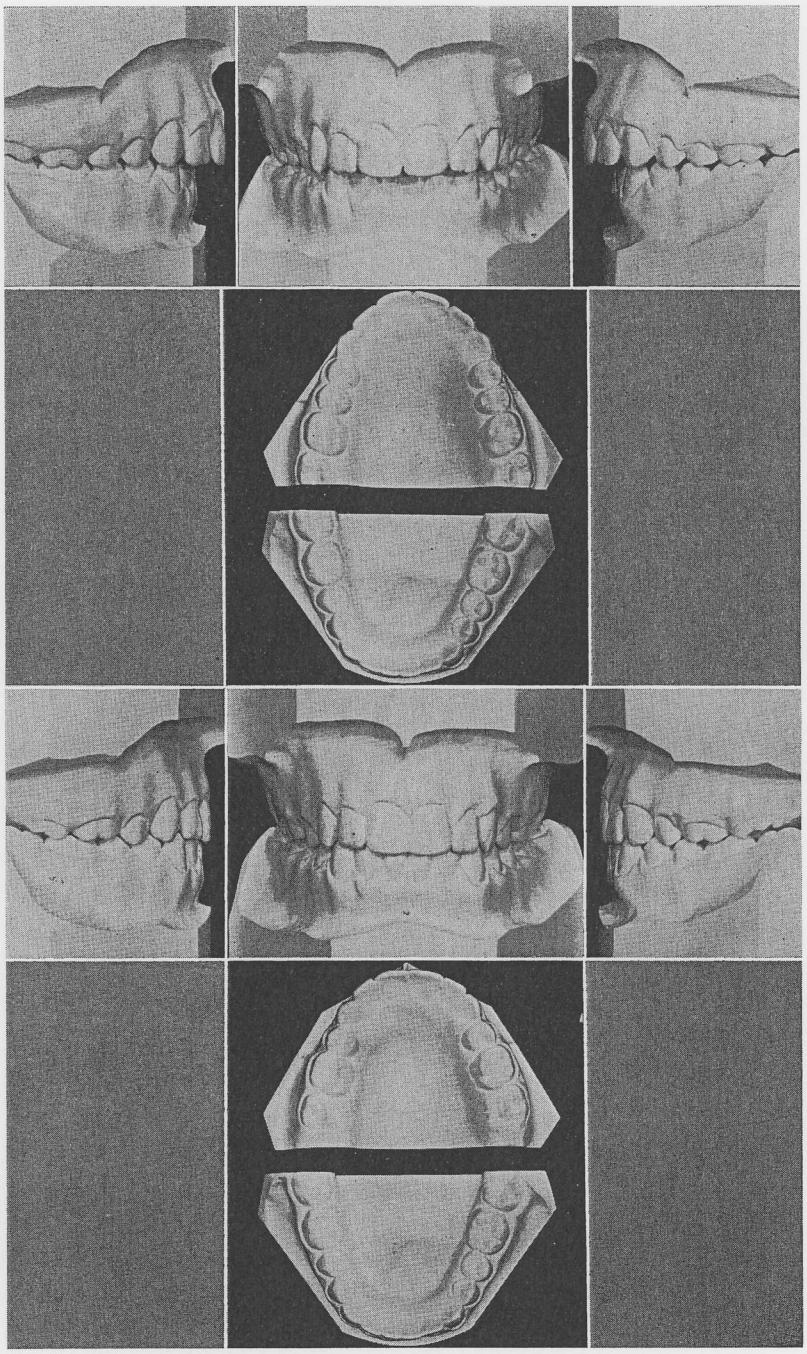

Fig. 8.

Fig. 7. A setup of the malocclusion shown in Fig. 6, maintaining a full complement of teeth.

Fig. 8. A setup of the case shown in Fig. 6, after the extraction of the maxillary second premolars and anterior stripping.

ratio readings for this patient were 82.8 and 70.3, respectively; this indicates that the maxillary arch is too large for the existing mandibular arch. The setup shown in Fig. 7 bears this out. With the first molars placed in a Class I relationship, it is obvious that a marked discrepancy in tooth size exists between the two arches. Not only is there a marked maxillary anterior overjet, but the disharmony also extends to the buccal segments, making it impossible to obtain proper canine and premolar interdigitation.

By substituting in the over-all formula, $\frac{\text{Sum mandibular 12 (87)}}{\text{Sum maxillary 12 (X)}} \times 100 =$ 91.3 (mean), and solving, X was found to be 95.3. This is 9.7 mm. smaller than 105 mm., the actual measurement recorded; therefore, the maxillary arch is excessive by 9.7 mm. Then by substituting in the anterior ratio, $\frac{\text{Sum mandibular 6 (36)}}{\text{Sum maxillary 6 (X)}} \times 100 = 77.2$ (mean), and solving, we find that X is 46.7 mm. By subtracting 46.7 from the 52.0 that existed, it is seen that the maxillary anterior segment is excessive by 5.3 mm. This leaves 4.4 mm. of the over-all excess to be confined to the buccal regions.

A setup of this case (Fig. 8) was made by removing 5 mm. of tooth structure from the maxillary anterior segment by the stripping of the mesial and distal surfaces of the four incisors and the mesial surface of the canines. Extraction was considered necessary in the maxillary arch, so the second premolars were removed and the first molars were brought forward into a Class II molar relationship. This allowed satisfactory intercuspation in the buccal segments, which previously had not been possible.

Of clinical significance is the fact that the analysis can be so quickly and easily carried out. From a set of casts the various tooth measurements on each dental arch are punched along straight lines drawn upon a card. The dimensions can then be determined by means of a finely calibrated millimeter ruler. The ratios are then set up and the results are compared to the means published here. If a marked deviation occurs, a diagnostic setup can verify and give the exact picture of the conditions that exist which will affect the plan of treatment. It is thought that the ratio results can give one an insight as to how the setup should be approached, that is, which teeth might most logically be extracted if such a procedure is deemed necessary. It must also be pointed out that the need for the extraction of a tooth or teeth is not necessarily confined to the case in which shortened arch length exists. Gross disharmonies in tooth size may indicate the removal of a dental unit or units, even where there is adequate arch length. Conversely, tooth-size discrepancies may be corrected by the placing of overcontoured restorations where indicated.

Mesiodistal diameter figures for all the teeth were taken from Wheeler's[10] text on dental anatomy. These dimensions were considered to be ideal for the carving and articulating of the teeth in making the perfect setup. When his figures were used and the ratios were computed, the results were found to be 91.4 for the over-all ratio and 77.8 for the anterior ratio. This correlates closely with results derived from this study.

A comparison of widths of anterior segments of artificial teeth when set up (data published by the Dentists Supply Company of New York) showed that the mean of the anterior ratios for sixty-one molds was 76.86.*

During the search for excellent occlusions a striking example of a man-made discrepancy in tooth size was discovered. The occlusal views of the case (Fig. 9) show very well how the mesiodistal diameters of all the teeth comprising the maxillary buccal segments except the right first premolar have been increased by the overcontouring of restorations. The measurement of casts made before and after operative dentistry procedures and orthodontic treatment revealed that the maxillary buccal segment (excluding second molars) had been increased in length by 2 mm. on the left and by 1.25 mm. on the right side.

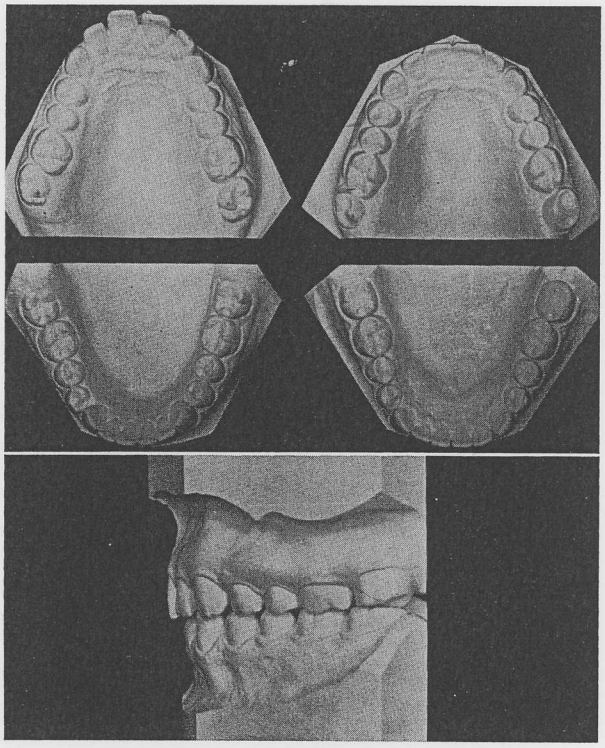

Fig. 9. An example of a man-made disharmony caused by the placement of overcontoured restorations.

The corresponding mandibular segments had been increased in dimension also, but by only a negligible amount (approximately 0.25 mm.). Fewer restorations were present in the mandibular denture.

The effect of overcontoured restorations on occlusal relationship is best illustrated by the left lateral view shown in Fig. 9. The molars are in a good Class I relationship, but it is clearly demonstrated that the canine and premolar

*These figures were based upon mathematically determined relationships.

pattern of occlusion is faulty, this portion of the maxillary buccal segment being anteriorly placed in relation to the mandibular segment. This is a good illustration of the way in which an overzealous dentist can alter tooth size to the extent that arch length is shortened.

CLINICAL APPLICATION

This portion of the study will demonstrate the need for analyzing, from the standpoint of tooth size, all malocclusions presented to us as clinical orthodontists. It is hoped that measurements and the establishment of over-all and anterior ratios will show a method that will give a mathematical answer to the question of articulation, which in the past could be resolved only by the construction of a diagnostic setup.

In a sample of 100 cases from my practice it was found that twenty-nine presented an anterior discrepancy of greater than one standard deviation (1.65 for a mean of 77.2). In an unpublished study made by Richardson at the University of Washington in 1959, 205 cases were measured; of these, seventy-nine presented a tooth size disharmony greater than one standard deviation (33.7 per cent). The high percentages would indicate a need for diagnostic consideration.

At the time the original records on a given case are evaluated the various tooth measurements on each dental arch are taken from the casts and punched upon a card, along straight lines from a common midline. The dimensions can then be determined from the use of a finely calibrated millimeter ruler.

Fig. 10 shows a simple analysis sheet devised to eliminate the need for computing the mathematical ratios. The figures are arranged in two columns, the first showing a given maxillary reading and the second showing the ideal mandibular counterpart. Comparisons can be made rapidly, and the operator with only minimal experience can soon learn to predict accurately the occlusal outcome of the case under investigation.

From the excellent occlusion shown in Fig. 2, the following ratio determinations were made:

$$\frac{81}{89} \times 100 = 91.1 \text{ (over-all)}$$

$$\frac{35.5}{45.75} \times 100 = 77.6 \text{ (anterior)}$$

If this dentition were in a state of malocclusion so that the final occlusal result could not be visualized but could be corrected on a nonextraction basis, one would assume from the excellent ratio readings that a nearly ideal intermaxillary articulation could be achieved. The excellence of the occlusion lends validity to the ratio results, since the values in this case are so very near the means derived from the sample of fifty-five excellent occlusions.

If the dentition is in a state of malocclusion with shortened arch length which necessitates the removal of four premolars, an elaboration on the ratio method becomes necessary. There are several fundamentals which become apparent as one's experience in the field of tooth size and occlusal harmony increases.

ANALYSIS OF TOOTH-SIZE DISCREPANCIES

Over-all Ratio

$$\frac{\text{Sum mandibular 12}\_\_\_\_\_\text{mm.}}{\text{Sum maxillary 12}\_\_\_\_\_\text{mm.}} = \_\_\_\_\_ \times 100 = \frac{\_\_\_\_\_\%}{\text{Over-all ratio}}$$

Mean 91.3 = 0.26
S.D. (o) 1.91
Range 87.5-94.8

Maxillary 12	Mandibular 12	Maxillary 12	Mandibular 12	Maxillary 12	Mandibular 12
86	77.6	94	85.8	103	94.0
86	78.5	95	86.7	104	95.0
87	79.4	96	87.6	105	95.9
88	80.3	97	88.6	106	96.8
89	81.3	98	89.5	107	97.8
90	82.1	99	90.4	108	98.6
91	83.1	100	91.3	109	99.5
92	84.0	101	92.2	110	100.4
93	84.9	102	93.1		

Patient Analysis

If the over-all ratio exceeds 91.3 the discrepancy is in excessive mandibular arch length. In above chart locate the patient's maxillary 12 measurement, and opposite it is the correct mandibular measurement. The difference between the actual and correct mandibular measurement is the amount of excessive mandibular arch length.

$$\frac{\text{Actual mandibular 12}}{} - \frac{\text{Correct mandibular 12}}{} = \frac{\text{Excess mandibular 12}}{}$$

If over-all ratio is less than 91.3:

$$\frac{\text{Actual maxillary 12}}{} - \frac{\text{Correct maxillary 12}}{} = \frac{\text{Excess maxillary 12}}{}$$

Anterior Ratio

$$\frac{\text{Sum mandibular 6}\_\_\_\_\_\text{mm.}}{\text{Sum maxillary 6}\_\_\_\_\_\text{mm.}} = \_\_\_\_\_ \times 100 = \frac{\_\_\_\_\_\%}{\text{Anterior ratio}}$$

Mean 77.2 = 0.22
S.D. (o) 1.65
Range 74.5-80.4

Maxillary 6	Mandibular 6	Maxillary 6	Mandibular 6	Maxillary 6	Mandibular 6
40.0	30.9	45.5	35.1	50.5	39.0
40.5	31.3	46.0	35.5	51.0	39.4
41.0	31.7	46.5	35.9	51.5	39.8
41.5	32.0	47.0	36.3	52.0	40.1
42.0	32.4	47.5	36.7	52.5	40.5
42.5	32.8	48.0	37.1	53.0	40.9
43.0	33.2	48.5	37.4	53.5	41.3
43.5	33.6	49.0	37.8	54.0	41.7
44.0	34.0	49.5	38.2	54.5	42.1
44.5	34.4	50.0	38.6	55.0	42.5
45.0	34.7				

Patient Analysis

If anterior ratio exceeds 77.2:

$$\frac{\text{Actual mandibular 6}}{} - \frac{\text{Correct mandibular 6}}{} = \frac{\text{Excess mandibular 6}}{}$$

If anterior ratio is less than 77.2:

$$\frac{\text{Actual maxillary 6}}{} - \frac{\text{Correct maxillary 6}}{} = \frac{\text{Excess maxillary 6}}{}$$

Fig. 10. An analysis sheet devised to eliminate the need for computing the over-all and anterior ratios.

The dental arches must be thought of as consisting of two components, the anterior and the posterior. The ratio of 77.2 ± 1.65 for the anterior segment, $\frac{\text{mandibular } 6}{\text{maxillary } 6} \times 100$, is very specific; it should be considered as a completely independent unit and given our first attention. Much of denture stability and and proper esthetics depends upon a normal overbite-overjet relationship with proper intercuspation in the canine regions, and this is what a ratio of 77.2 ± 1.65 should give if angulation of incisors is proper and labiolingual thickness is not excessive.

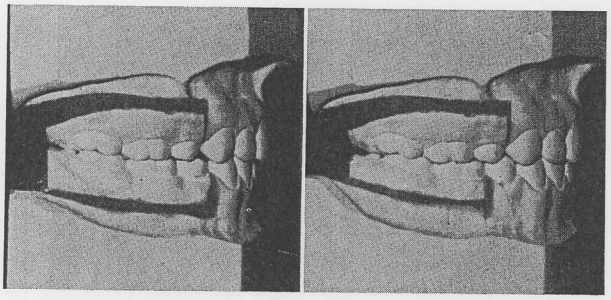

Fig. 11. Fig. 12.

Fig. 11. A setup of the ideal occlusion casts after the removal of the first premolars of equal size.

Fig. 12. A setup of the ideal occlusion casts after the removal of a larger mandibular second premolar.

The profile view of the diagnostic setups shown in Figs. 11 and 12 portrays an excellent anterior ratio and brings us to the point of considering what might be expected from the over-all ratio when premolar units are extracted. Since the dental arches are arcs of different lengths, an unusual mathematical situation is encountered if equal-sized premolars are removed from each quadrant.

For example, if a hypothetical ratio is established, such as a maxillary measurement of 100.0 mm. and a mandibular measurement of 91.0 mm., we would have an excellent occlusal prognosis on the basis of our ratio, $\frac{91 \text{ mandibular } 12}{100 \text{ maxillary } 12} \times 100 = 91.0$ per cent. If we now subtract 14 mm. (an acceptable determination for two premolars) from both of the full arch measurements, the following ratio is established:

$$\frac{(91\text{-}14)\ 77 \text{ mandibular } 12}{(100\text{-}14)\ 86 \text{ maxillary } 12} \times 100 = 89.5 \text{ per cent.}$$

Conversely, if the same amount (14 mm.) is added to our arbitrary sums, the following result is obtained:

$$\frac{(91+14)\ 105 \text{ mandibular } 12}{(100+14)\ 114 \text{ maxillary } 12} = 92.1 \text{ per cent.}$$

The readings 89.5 per cent and 92.1 per cent are very satisfactory, both lying within one standard deviation of the mean, but the numerical value obtained from our arbitrary ratios is not the important factor in this instance. The important thing is that one understand how a ratio set up between arcs of unequal length (such as dental arches) will not remain constant when segments (premolars) of equal width are removed from each arc.

The practical example of this is the dentition which presents an ideal over-all ratio but is in need of premolar extraction. If the maxillary and mandibular premolars are of equal mesiodistal width, it will be found in the average case that the over-all ratio value will decrease by approximately two percentage points, usually from 91.0+ to 89.0 per cent. In order for the ratio to remain constant, it becomes necessary to remove more tooth structure in the maxillary arch, by approximately 1 mm. per premolar. The information on premolar sizes set forth in Table IV shows that, according to the mean widths, it would be

Table IV

Teeth compared	*Mean*	*r*
1. Maxillary first premolar	7.04	0.96
Mandibular first premolar	7.15	
2. Maxillary second premolar	6.84	0.50
Mandibular second premolar	7.27	
3. Maxillary first premolar	7.04	0.57
Mandibular second premolar	7.27	
4. Maxillary second premolar	6.84	0.61
Mandibular first premolar	7.15	

the exception rather than the rule for the ratio to be maintained. This statistical evidence points out the tendency for the mandibular premolars to have a greater mesiodistal dimension than their maxillary counterparts; therefore, the over-all ratio should not be used as a specific guide to the predicted occlusion after the removal of four premolars. Rather, clinical observation and experience cause the following recommendation to be made in the premolar-extraction case. The individual tooth measurements are made and recorded, and the ratios are established. Under ideal circumstances, the anterior reading will be 77.0 per cent and the over-all reading will be 91.0 per cent. With these results and the elimination of the four premolar measurements, the 77.0 per cent anterior reading, of course, remains unchanged while the 91.0 per cent over-all reading will be reduced to approximately 89.0 per cent if both the maxillary and mandibular premolars are of equal size. If the mandibular premolars are of greater mesiodistal dimension, as is often the case, the ratio reading may even be reduced to as little as 87.0 per cent. This is thought to be desirable in the case in which the anterior relationships are excellent (77.0 per cent). The additional tooth structure removed from the mandibular posterior segments causes a shortening of the mandibular arc which disrupts the over-all ratio (reduces it from an expected 89.0 per cent to approximately 87.0 per cent), but clinically we see an

improvement in the posterior occlusion as the mandibular molars are allowed more mesial movement. The mesial positioning of these molars permits a slight super Class I relationship to be obtained which, in turn, will allow the distal cusps of the maxillary first molars to dip more securely into the sulcus between the mandibular first and second molars. Many clinical orthodontists believe that the type of maxillary first molar positioning just described is one of the important keys in orthodontic stability.

Fig. 11 demonstrates a setup of the ideal occlusion casts following the removal of first premolars of equal size. The occlusal result is a satisfactory one, but careful examination of the casts shown in Fig. 12 where a larger (1 mm.) mandibular second premolar was removed shows an improvement in the degree of occlusal excellence. This statement should not be interpreted as a broad recommendation for extraction of mandibular second premolars, but this tooth is often the largest of the premolars; therefore, this fact bears consideration in the over-all analysis and treatment plan.

In the cases in which a disharmony exists and the ratio results do not fulfill the requirements of 91.0 and 77.0 per cent for the over-all and anterior ratios, respectively, the orthodontist must consider steps to give a finished product which will be in occlusal balance. The steps may range from the stripping of teeth to reduce mesiodistal width to the unusual extraction which will put the tooth-size discrepancy case in harmony. A combination of the two steps is often recommended. In the extreme situation the solution may involve the placing of overcontoured restorations to give added width to a tooth or a segment of teeth.

Fig. 13 portrays a severe Class II, Division 1 malocclusion in which it was deemed necessary to remove dental units. The full arch readings are 91.1 per cent for the over-all ratio (91.3 per cent mean) and 77.3 per cent (77.2 per cent mean) for the anterior ratio. One would expect, on a nonextraction basis, an ideal occlusal relationship. This practical case is an excellent example of the previous discussion.

The anterior ratio was computed by substitution in the formula $\frac{\text{mandibular } 6}{\text{maxillary } 6} \times 100$ or $\frac{35.0}{45.25} \times 100 = 77.3$ per cent, and the over-all ratio was also solved, $\frac{\text{mandibular } 12}{\text{maxillary } 12} \times 100$ or $\frac{87.0}{95.5} \times 100 = 91.1$ per cent. The extraction of four first premolars, whose widths are 7.0 mm. each, would change the over-all ratio to $\frac{73.0}{81.5} \times 100$ by subtracting 14.0 mm. from each arch. The ratio result will change from 91.1 to 89.6 per cent with this choice of extractions. The posterior occlusion prognosis would be very satisfactory, harmonizing well with the nearly ideal anterior ratio of 77.3 per cent.

In this instance the mandibular second premolars were wider mesiodistally by 1 mm. each. They were chosen for extraction. This change from the previous decision to extract first premolars changed the ratio by an additional 2 mm.

Fig. 13.

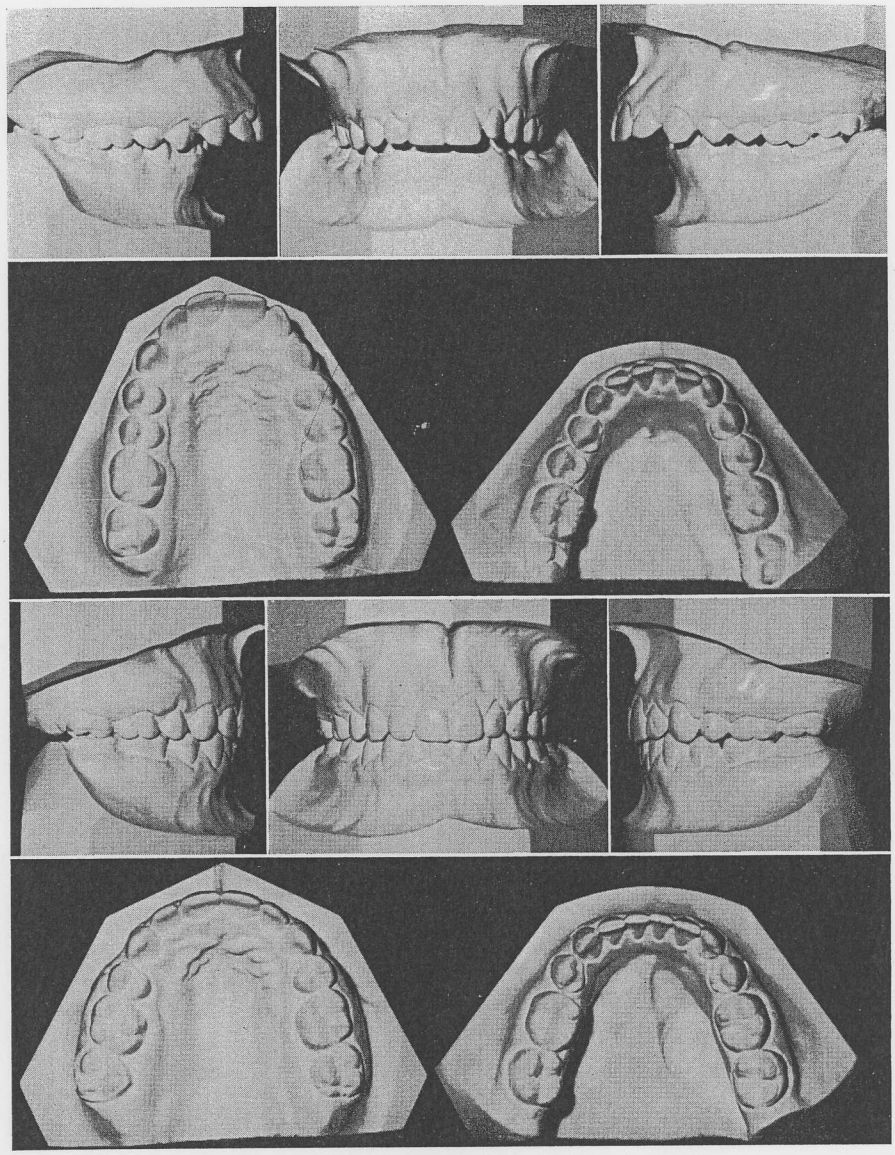

Fig. 14.

Fig. 13. A malocclusion requiring extraction which has excellent tooth-size ratio readings.
Fig. 14. The finished treatment result of the case shown in Fig. 13. The maxillary first premolars and the mandibular second premolars have been extracted.

being removed from the mandibular arch. The ratio of $\frac{73.0}{81.5} \times 100$ for first premolars was changed to $\frac{71.0}{81.5} \times 100$ when mandibular second premolars were extracted, and the result was changed from 89.6 to 87.1. The ratio changes

Fig. 15.

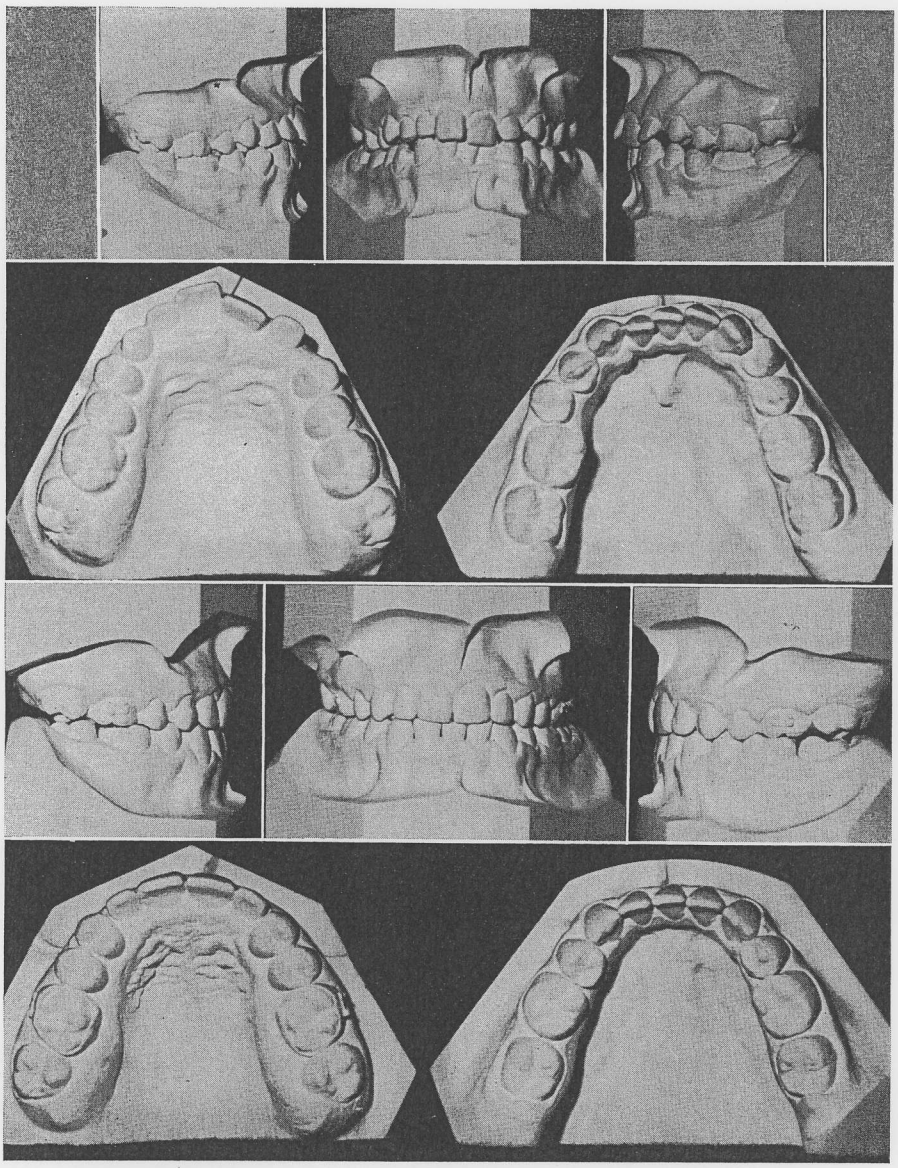

Fig. 16.

Fig. 15. A malocclusion with shortened arch length and absence of one mandibular incisor.
Fig. 16. The treatment result of the case shown in Fig. 15 following extraction of the maxillary canines and the mandibular first premolars.

noted here are very typical of those found in extraction cases in which the tooth-size ratios are in agreement with the recommended means prior to the extraction procedure.

Fig. 14 shows the finished treatment result. Removal of the larger mandibular second premolars allowed additional mesial movement of the first molar which, in turn, improved its relationship with the maxillary first molar.

The malocclusion shown in Fig. 15 is a Class I type with maxillary canines impacted and the mandibular left lateral incisor missing. Arch length is inadequate to the point where extraction must be considered. The maxillary right deciduous canine is still in place.

From a purely mechanical standpoint, it was felt that the logical extraction choices would be the maxillary canines, because of their very poor positions, and the mandibular first premolars, because of the degree of shortened arch length. This combination was considered logical also because it appeared that the maxillary lateral incisors were undersized and the mandibular incisors large. The application of the tooth-size analysis with its two basic ratios demonstrated, from the standpoint of a full complement of teeth (aside from the missing mandibular incisor), that good occlusal relationships were possible. The anterior percentage was 75.5, while the over-all ratio was 90.6 per cent.

If the maxillary canines were eliminated and the first premolars were of the same mesiodistal width, to complete the maxillary anterior segment, the anterior ratio would not be disturbed. The ratio was $\frac{\text{mandibular } 6\ (34)}{\text{maxillary } \quad 6\ (45)} \times 100 = 75.5$ per cent; this showed a 0.7 mm. maxillary excess. The decrease in total length of arches by extraction of the maxillary canines and the mandibular first premolars (plus the missing incisor) gave the following ratio: $\frac{\text{mandibular } 12}{\text{maxillary } \quad 12}$ $\frac{(72.0)}{(82.0)} \times 100 = 88.4$ per cent. For the dental arches which have undergone a marked decrease in length because of the extraction of teeth, this is a very satisfactory relationship.

Fig. 16 shows the case at the time appliances were removed. It was felt that the mathematical sums derived from the two basic ratios gave us a simple and rapidly developed key to our final esthetic and functional result without the use of a diagnostic setup. It is reasoned that the best retaining device in a case of this type, with its rather unusual extraction choices and slight open-bite tendency, is a silicone rubber positioner. It is used for a short period (from three to six weeks) prior to the placement of rigid, more long-term appliances.

Fig. 17 shows a Class II, Division 1, Subdivision malocclusion complicated by the presence of grossly undersized maxillary lateral incisors and the congenital absence of the mandibular left lateral incisor. For this particular facial pattern, the extraction of teeth was considered to be illogical. The case was analyzed from a tooth-size standpoint. The over-all ratio indicated a 1.6 mm. maxillary excess, and the anterior ratio showed a 2.7 mm. maxillary excess.

The relationship of the ratio percentages indicated that the disharmony lies mainly in the anterior segments. It was reasoned that if 2.0 mm. of tooth material could be removed from the mesial and distal surfaces of the maxillary central incisors and canines harmony would result. The teeth were stripped in the heavy enamel areas, the appliance was constructed and placed, and the treatment was carried out according to the original plan.

Fig. 17.

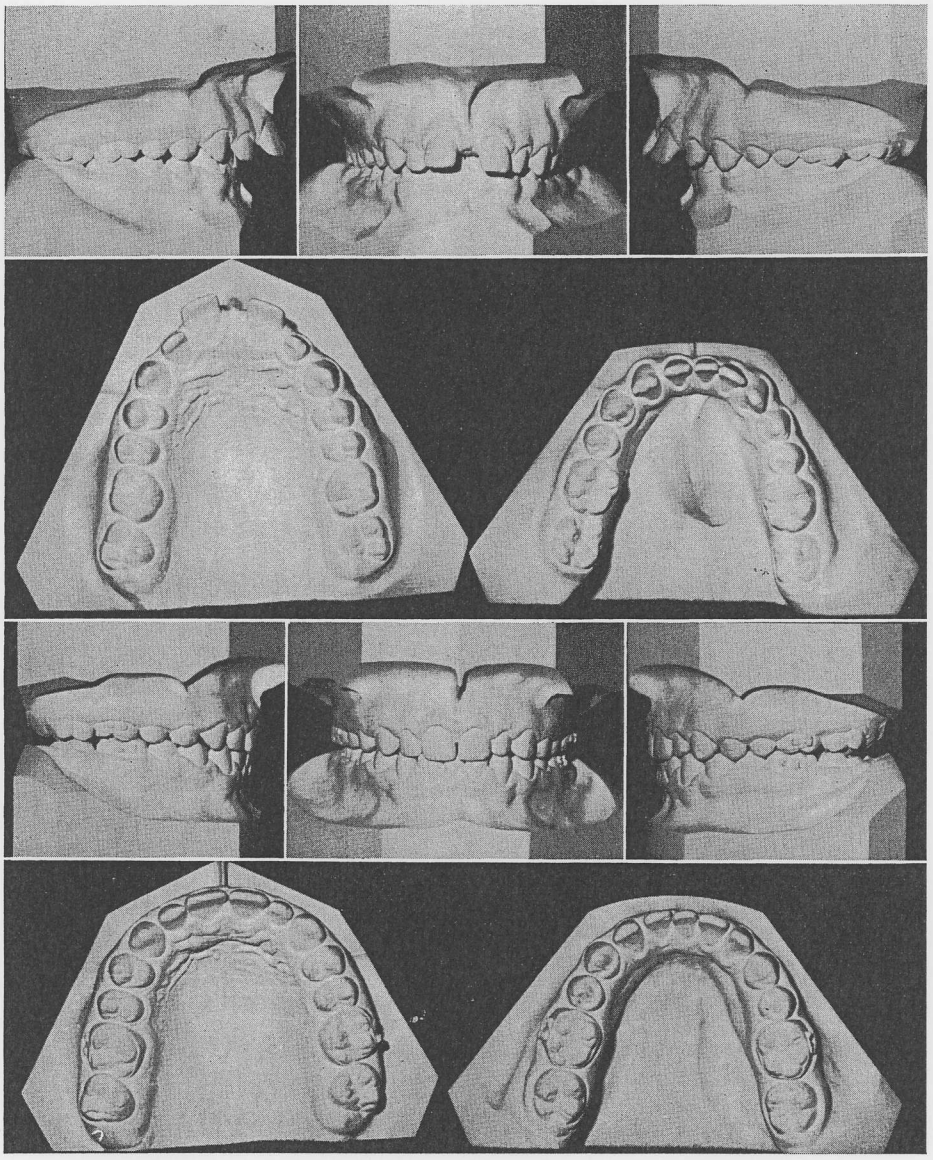

Fig. 18.

Fig. 17. A malocclusion complicated by maxillary peg lateral incisors and the absence of one mandibular incisor.

Fig. 18. The treatment result of case shown in Fig. 17, at the time of appliance removal. This case was treated on a nonextraction basis.

The casts shown in Fig. 18 were made at the time of appliance removal. Again, it was felt that the disharmony analysis gave us an immediate insight into the possible approaches to treatment as indicating the area and degree of size discrepancy.

Fig. 19.

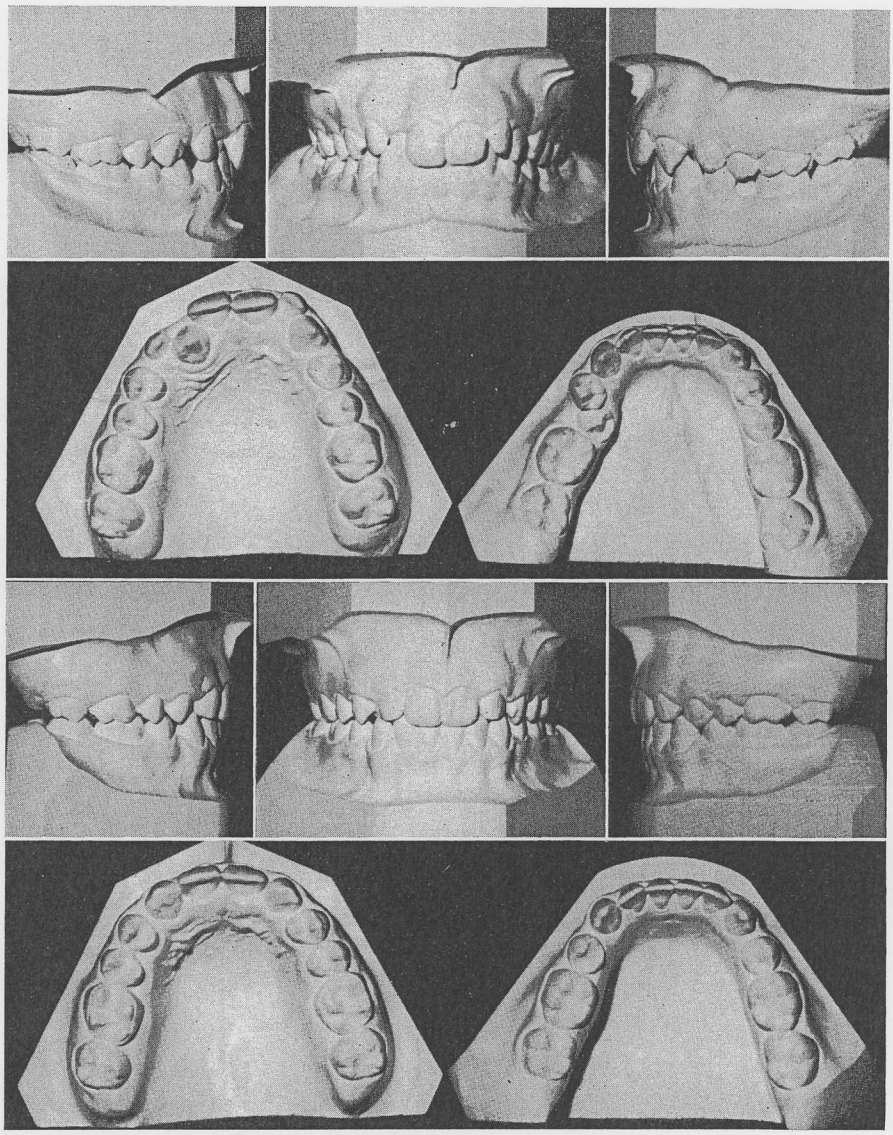

Fig. 20.

Fig. 19. A malocclusion which presents shortened arch length, maxillary peg lateral incisors, and a transposition of the maxillary right lateral incisor and canine.

Fig. 20. The treatment result following extraction of maxillary lateral incisors and mandibular first premolars.

The case presented in Fig. 19 is a Class I malocclusion with two unusual situations present in the maxillary arch. Both oddities are related to the lateral incisors. They are not only peg-shaped, but on the right side the canine and the lateral incisor have become transposed. The mandibular arch presented moderate crowding, chiefly confined to the area of the left second premolar.

Fig. 21.

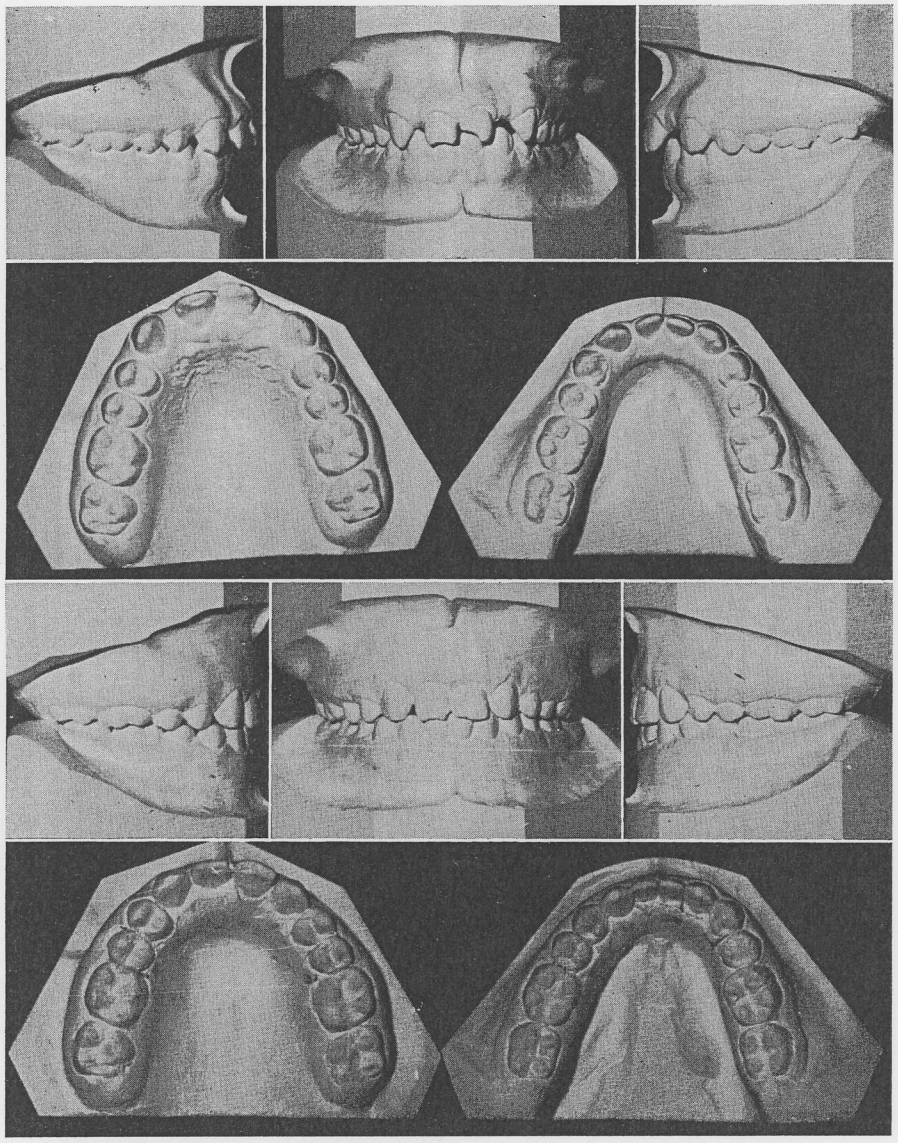

Fig. 22.

Fig. 21. A malocclusion with the congenital absence of maxillary and mandibular lateral incisors.

Fig. 22. A setup of the case shown in Fig. 21 after removal of 1.5 mm. of tooth structure from the mandibular anterior segment.

It was found that, from the full complement standpoint, the over-all ratio indicated a 4.0 mm. mandibular excess while the anterior ratio showed a 3.1 mm. mandibular excess. This particular relationship of ratio values would indicate that the main discrepancy in size was confined to the anterior segments.

It was considered feasible, on the basis of all other diagnostic data, to correct this malocclusion by the extraction of the maxillary lateral incisors and the mandibular first premolars. By establishing new ratios, with the substitution in the maxillary arch of canines for lateral incisors and first premolars for canines, a result was obtained which indicated only a 0.9 mm. maxillary excess in the anterior segment. The new over-all ratio established after the removal of the mandibular first premolars demonstrated a 0.4 mm. mandibular excess. Both results were so near the mean figures (79.0 per cent anterior and 90.8 per cent over-all) that it was decided to treat the malocclusion and to do any necessary size adjusting in the retention stage of treatment. Fig. 20 shows the result several months out of retention.

The last practical case to be demonstrated is an unusual and difficult one from the tooth-articulation standpoint (Fig. 21). The patient presented a Class I malocclusion complicated by the congenital absence of both the maxillary and mandibular lateral incisors and a severe tongue-thrusting habit. In this situation the over-all ratio took on real significance, with a reading of 92.2 per cent, compared to the mean of 91.3 per cent, which indicated a mandibular excess of only 1 mm.

When six teeth were placed in each anterior segment, substituting lateral incisors for canines and canines for premolars, and the ratio was computed, it was found that a 3.5 mm. mandibular excess resulted. This finding was not compatible with the over-all ratio. The ratio was then developed using only the four anterior teeth—the central incisors and canines. An 80.0 per cent value was derived, which also indicated a 1.0 mm. mandibular excess. This was considered to be the valid and desirable approach.

The diagnostic setup shown in Fig. 22 demonstrated the occlusal result obtained by removing approximately 1.5 mm. of tooth structure from the mandibular incisors and canines. The reason for the much greater disharmony when six were included in the anterior ratio is not clearly understood, unless there was an abnormality of tooth morphology which was peculiar to this case.

When the treatment problem calls for extraction of two maxillary premolars only the tooth-size ratios as outlined can also be utilized to advantage. The ratios are established in the same manner as in a nonextraction case. If the values are in agreement with the recommended means, and if the width of the maxillary premolar to be extracted is the same as the distance from the mesial surface of the maxillary first molar to the height of its distal cusp, the occlusion should be satisfactory, even though a Class II molar relationship is the result.

As a finale to this review of cases, it should be pointed out that there are two distinct situations which can alter the anterior relationships and ratios.

In the natural denture where the mandibular incisors are upright but the maxillary incisors are in extreme labial inclination, the size relationship will be disturbed. An excess amount of tooth structure in the maxillary anterior segment is needed if all spaces are to remain closed. In general, one must guard against the extreme bimaxillary protrusion with its small interincisal angle, not only from the standpoint of esthetics and stability but also with respect to disruption of the tooth-size ratio. In the case involving a small interincisal angle

a good ratio result does not necessarily mean a good relationship of anterior teeth, with proper interdigitation in the canine regions, unless an edge-to-edge bite is the result or the mandibular anterior segment is reduced in size.

Rarely a dentition may be found in which extreme labiolingual thickness is noted or in which the marginal ridges of the incisors are extremely pronounced in the maxillary arch. Under these circumstances, an excess in the maxillary anterior segment may also be necessary to bring about what is considered a normal overbite-overjet relationship with stable space closure. It is believed that there are indications for removing portions of extremely oversized marginal ridges of the maxillary incisors in order to establish the proper overjet relationship.

SUMMARY AND CONCLUSIONS

For the sake of continuity in the presentation of tooth-size ratios and their clinical application, it was deemed necessary to review the portion of the original study dealing with the over-all and anterior ratios and their development. From the original presentation, it has been found that the data concerning the over-all and anterior ratios have clinical significance. When the twelve maxillary teeth were compared with the twelve mandibular teeth in a ratio, as $\frac{\text{sum mandibular 12}}{\text{sum maxillary 12}} \times 100 =$ over-all ratio, a statistically significant mean, standard deviation, and coefficient of variation were found to exist. They were 91.3 ± 0.26, 1.91, and 2.09 per cent, respectively.

The anterior ratio is produced in a similar manner, involving the six maxillary anterior teeth and the six mandibular anterior teeth as $\frac{\text{sum mandibular 6}}{\text{sum maxillary 6}} \times 100 =$ anterior ratio. Equally significant findings were obtained. For a mean of 77.2 ± 0.22, the standard deviation was 1.65 and the coefficient of variation was 2.14 per cent.

The main body of the work presented here is concerned with the clinical application of the ratios. Treatment problems of various types were selected. The technique, the actual measurements, and interpretation were demonstrated for several different types of malocclusion.

1. Hypothetical ratios were developed to demonstrate changes in result as arch length is increased or decreased.

2. The consideration of mesiodistal width in making the proper premolar-extraction choices was brought forth. The excellence of occlusion in the extraction case may often be improved by the removal of a mandibular premolar that is larger than the maxillary premolar.

3. The extraction cases presented, along with their respective tooth-size analyses, were varied to demonstrate the application of size ratios to as many different situations as possible. The combinations were as follows:

   a. Four premolars
   b. Maxillary canines, mandibular premolars, and one mandibular incisor

c. One mandibular incisor
d. Maxillary lateral incisors and mandibular first premolars
e. Maxillary and mandibular lateral incisors

4. The case requiring extraction of two maxillary premolars was discussed in terms of the application of tooth-size ratios.

5. The two main clinical features which may disrupt the anterior tooth-size ratio were presented. They are (1) extreme labial inclination of incisor teeth with the resultant small interincisal angle and (2) the situation in which the incisors have extreme labiolingual thickness.

The clinical application of the ratios devised has been presented. After eight years of applying these ratios to practical cases, I believe that there is rarely a need for the diagnostic setup. A knowledge of the mathematical approach to occlusion plus an observant eye can localize many a disharmony which even a setup may not demonstrate clearly. Of clinical significance is the fact that the measurements are easily and quickly made, making the analysis a practical diagnostic tool.

REFERENCES

1. Ballard, M. L.: Asymmetry in Tooth Size: A Factor in the Etiology, Diagnosis, and Treatment of Malocclusion, Angle Orthodontist **14**: 67-71, 1944.
2. Black, G. V.: Descriptive Anatomy of the Human Teeth, ed. 4, Philadelphia, 1902, S. S. White Dental Mfg. Co.
3. Bolton, W. A.: Thesis for Master's Degree, University of Washington, 1952.
4. Bolton, W. A.: Disharmony in Tooth Size and Its Relation to the Analysis and Treatment of Malocclusion, Angle Orthodontist **28**: 113-130, 1958.
5. Cooper, W. S.: Thesis for Master's Degree, University of Washington, 1960.
6. Lundstrom, A.: Intermaxillary Tooth Width Ratio and Tooth Alignment and Occlusion, Acta odont. scandinav. **12**: 265-292, 1954.
7. Neff, C. W.: Tailored Occlusion With the Anterior Coefficient, Am. J. Orthodontics **35**: 309-314, 1949.
8. Steadman, S. R.: Predetermining the Overbite and Overjet, Angle Orthodontist **19**: 101-105, 1949.
9. Stifter, J.: A Study of Pont's, Howes', Rees', Neff's and Bolton's Analyses on Class I Adult Dentitions, Angle Orthodontist **28**: 215, 1958.
10. Wheeler, R. C.: Textbook of Dental Anatomy and Physiology, ed. 4, Philadelphia, 1940, W. B. Saunders Company.
11. Principles of Selection and Articulation, New York, 1939, The Dentists' Supply Company of New York.

4th & Pike Bldg.