Assessment of Mandibular Arch Length Discrepancy Utilizing an Individualized Arch Form

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INTRODUCTION

The purposes of this paper are: (1) to evaluate the accuracy of the two most popular methods of estimating arch length discrepancy, (2) to present a different method for assessing arch length discrepancy and (3) to compare this method for assessing arch length discrepancy with the methods in current use.

As the science and art of orthodontic treatment has evolved, it would appear that the introduction of the cephalometric analysis has allowed our profession a closer association with the science aspect than with the equally important, but sometimes nebulous art consideration. Cephalometric analysis has permitted us to evaluate treatment methods better. It has contributed to the delineation of areas of denture stability. It has provided a means of communication whereby a treatment plan may be discussed not only with reference to teeth, but also relative to changes affecting surrounding skeletal and soft tissue.

Two cephalometric analyses in wide use today, the Steiner[14] analysis and the Tweed[20] Diagnostic Facial Triangle analysis, provide the orthodontist with norms and ranges of conditions for dental stability. Variations from these norms give indication of the severity of the malocclusion. The application of additional diagnostic information to these analyses will allow the orthodontist to outline a clear-cut treatment plan and will indicate the mechanical steps necessary to achieve a predetermined area of dental permanence.

Both of the above analyses base their indications of denture stability on the proper positioning of the anterior segment of the mandibular dental arch.

Two areas of additional diagnostic information that are necessary to apply these cephalometric analyses are: (1) the number of millimeters involved in the relocation of the mandibular incisors and (2) the assessment of arch length discrepancy.

The figure for relocation of lower incisors can be arrived at directly by comparing the positions of the incisors in the malocclusion with those expected in the treatment goal. The difference between the two will give a figure indicating the distance and direction the mandibular incisors are to be moved.

The figure for arch length discrepancy or dental crowding is currently determined by personal judgment. The author believes that personal judgment, applied to an evaluation of this discrepancy, is insufficient and dangerous. Orthodontic treatment presupposes the accumulation and usage of accurate diagnostic information for each patient. Present methods for evaluating arch length discrepancy are not consistent and, in the author's opinion, are not accurate. A false impression of this value could alter an orthodontic treatment plan.

The present method of evaluating mandibular arch length discrepancy is to first estimate the arch length needed. Nance[11] used the term "space needed." The greatest mesiodistal widths of all permanent teeth mesial to the first mo-

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lars are added together. If deciduous teeth are still present, several methods are available to measure the widths of the succeeding permanent teeth.

The prediction charts of Carey,[5] Hixon,[7] Nance[11] or the University of Michigan[9] can be used. The size of a single unerupted permanent tooth can be determined through casts and intraoral x-rays using a proportion between the deciduous tooth and its successor.

From this information it can be seen that an assessment of "space needed" or arch length needed can be accomplished easily and checked by several methods. The problem arises when an attempt is made to compare "space needed" with "space available." The difference between the two is, of course, the arch length *discrepancy*.

One method currently in use for the determination of "space available" is a brass wire measurement. A length of brass wire is adapted to lie over the proximal contact areas of the teeth on the mandibular study cast from the mesial of one first molar around to the other molar. The length of the wire is accepted as being the "arch length available" or "space available."

The space available figure is compared with the space needed figure and the difference between the two is the arch length discrepancy. If deciduous second molars remain, it is Dr. Nance's contention that the leeway figure of 3.4 mm be subtracted from the space available figure. The limitation of the brass wire method is summed up in this sentence by Huckaba,[9] "In cases in which the teeth are badly crowded or overlapped, the mean arch alignment is used." This means that the orthodontist must use individual judgment in the determination of this mean alignment. Judgment, of course, is always valuable. However, a variation of three to five millimeters in individual judgment could mean the difference between an extraction and a nonextraction approach to treatment.

Another method of evaluating arch length discrepancy is the visual inspection method. This approach is perhaps more commonly used than the brass wire method and may be equally inaccurate. In this procedure the teeth are visually moved into arch alignment. The width of each overlap is mentally totaled and the sum of these overlaps is judged to be the arch length discrepancy. Some men augment their visual inspection by using a Boley gauge to measure each overlap.

We have thus far stated that both the Steiner and Tweed analyses base their treatment goals on the anteroposterior position of the lower dental arch. Dr. Tweed[19] suggests a basic 90° angular relation of the mandibular central incisors to the mandibular plane. Steiner[13] and Holdaway[8] have related the lower incisors to the line NB. Each of these men has accepted variation from his norm based on variation in the patient. However, the point is that acceptable positions for the mandibular anterior teeth have been established. The correct positioning of these lower teeth is a basis for positioning all other teeth. It also seems evident that the careful evaluation of arch length discrepancy is vital to desired tooth placement. A misjudged discrepancy figure might prevent the accomplishment of a treatment plan even though the mechanical application was faultless.

The brass wire method described for determining the arch length discrepancy clearly illustrates that the assessment of discrepancy is related to the interpretation of the *arch form* presented by the patient. However, the greater the crowding, the more the arch form is obscured.

What is currently known about the mandibular arch form? Thompson[17] demonstrates that arch form is not related to underlying bone morphology and that arch form is not related to tooth size. Larger teeth do not necessarily contribute to larger arch forms. This may conflict with the Bonwill-Hawley arch formation method and most certainly contradicts those who relate arch form to Pont's index.

What contributes to arch form? Graber[6] states that the integrity of the dental arch and the relationship of teeth to each other within each arch are the result of the morphogenetic pattern. The pattern is modified by the stabilizing and active functional activities of muscles.

Which arch form, maxillary or mandibular, is more important? Strang[16] states that the form of the maxillary denture is governed by the mandibular arch form. Thompson[17] believes that the recent trend of orthodontic diagnostic analysis and treatment planning has been to recognize that the mandibular denture is the principal limiting factor in determining the maxillary dental arch form.

Does the arch form change through growth? Brodie,[4] Strang, and Thompson clearly state that the morphology of the mandibular arch anterior to the first molars changes little after the basic arch pattern is established during the primary dentition stage. Nance,[11] Boone,[2] and Speck[12] noted that the transition between primary and permanent teeth does not change the arch length and arch form.

Can the mandibular arch form be altered mechanically without encouraging relapse? It was stated in the beginning of this paper that Tweed, Steiner and others have given us norms and ranges for positioning the anterior teeth. If the location of the anterior segment of the arch varies from these norms, a modification of the position of the anterior teeth toward these norms would generally improve denture stability.

Alteration of mandibular arch form laterally presents less leeway. Strang,[15] in reviewing his treatment results, stated that those cases he considered most stable were those in which there had been no lateral expansion whatsoever. Tweed[18] also considers the original lateral widths of the buccal segments to be inviolate. Thompson[17] states that "the muscular trough is that lateral extension wherein the teeth are found and where they should remain." Boone[2] states that "unplanned contraction or expansion, especially in the cuspid or molar region, produces instability."

Should arch form be preserved throughout orthodontic treatment? The above points would seem to indicate that we are dealing with a feature that is fairly stable in itself and, in addition, a feature whose stability of position we must preserve if we are to achieve overall denture permanence and not run the risk of relapse. Thompson states that there is a uniformity in the type of arch form which can be graphically constructed for individual arches. This is to say that the anteroposterior positioning of the anterior teeth of the mandible may vary according to the dictates of a careful cephalometric analysis. This also indicates that the lateral limits of the arch form usually should not vary from the time of the evaluation of the malocclusion to the time the case is completed.

This being the case, what methods can be used to assure maintenance of arch form? One method is to always keep the patient's study cast at hand so the archwire form can be directly related to the case. Another method is to construct individual arch formation charts that can be referred to throughout treatment as suggested by Boone and Thompson. A third method is the use of an occlusogram (a photocopy of the occlusal surfaces of the mandibular study cast). The latter record can be filed and referred to for each archwire modification.

One form or another of these methods must be utilized if constant control of expansion or contraction of lateral arch width is to be maintained. The positioning of anterior teeth can be checked with successive cephalometric head films.

If an accurate evaluation of arch length discrepancy is related to correct arch form, and if correct arch form is important for denture stability, might not the assessment of mandibular arch length discrepancy be linked to an individualized *Arch Form Chart?*

Methods and Materials

First Procedure

The purpose of this investigation was to evaluate the accuracy of the two most popular methods of measuring mandibular arch length discrepancy. Ten mandibular study casts were selected. Each study cast had an obvious amount of crowding. To avoid confusion in the prediction, no deciduous teeth were present in any of the study casts reviewed.

Ten senior orthodontic students from the University of Southern California School of Dentistry, Department of Orthodontics, were asked to evaluate the arch length discrepancy in each of the cases, both visually and by the brass wire technique.

The author had previously carefully measured the mesiodistal widths of the mandibular teeth from first molar to first molar for each of the ten cases and recorded the sums. These figures represented the arch length needed and were compared with the lengths of the brass wires. The difference between the arch length needed figure and the length of the brass wire, arch length available, represented one method for determining arch length discrepancy.

The figures arrived at by visual estimation represented the second method for evaluation of arch length discrepancy.

Dr. Keith Tanaka also contributed his estimations; with his participation we were provided with two hundred and twenty figures relating to arch length discrepancy.

Second Procedure

The purpose of this procedure was to present an improved method for assessing arch length discrepancy.

Lasher,[10] in 1934, stated that in a normal denture a line drawn through the contact points of the lower six anterior teeth formed a semicircle and, when a line was extended through the contact points of the bicuspids and molars, it formed a straight line.

With the above information as a basis, the following method for preparing an arch length discrepancy assessment evolved.

Arch Length Discrepancy Assessment

Step 1

On graph paper, lined with millimeter increments, draw a horizontal line near the top of the paper. This line is to be used for establishing the arch length needed (Fig. 1).

Draw another horizontal line in the middle of the paper and intersect it at its midpoint with a line drawn vertically. This middle section of the graph paper is to be the arch formation area.

Step 2

With fine pointed calipers measure the greatest mesiodistal width of each mandibular incisor, cuspid, and bicuspid. Transfer these measurements to the top line of the graph paper. The sum of these measurements is the arch length needed.

Step 3

Measure across the arch on the mandibular study cast from the mesial contact point of one first bicuspid to the mesial contact point of the other first bicuspid. Transfer this measurement to

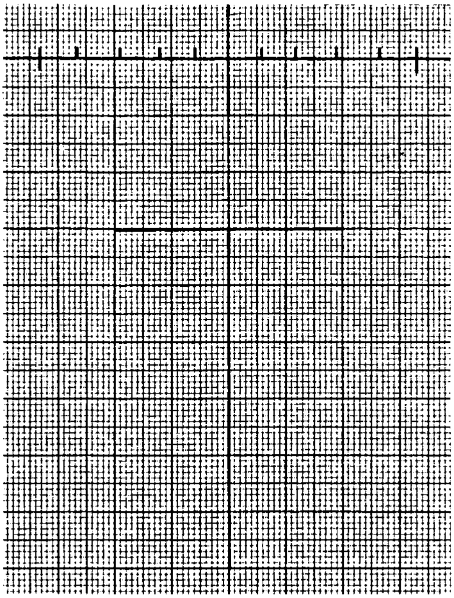

Fig. 1

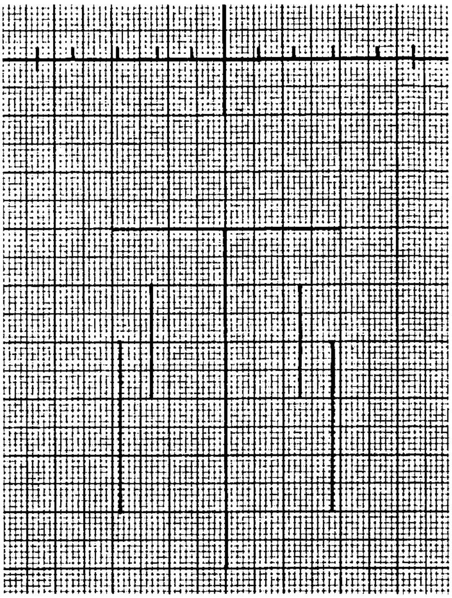

Fig. 2

the graph paper equidistant on each side of the vertical midline. Draw vertical lines through the extremities of this measurement (Fig. 2). This represents the lateral width of the arch form at the mesial contact points of the first bicuspids.

Step 4

Measure across the arch from the mesial contact point of one first molar to the mesial contact point of the other first molar. Transfer this measurement to the graph paper, equidistant on each side of the midline. Draw vertical lines through the extremities of this measurement (Fig. 2). This represents the lateral width of the arch form at the mesial contact points of the first molars.

Step 5

Cut a piece of .025 brass wire accurately to the length of the arch length needed. Mark the brass wire at the locations of the midline and the mesial contact points of each first bicuspid.

Step 6

Form the brass wire into a tentative arch form and lay on the graph paper. The midline of the wire should lie where the horizontal and vertical guide lines of the arch formation area intersect. Make the marks representing the mesial contact points of the first bicuspids cross the vertical first bicuspid lateral width marks that were established in Step three. Make the ends of the brass wire, which represent the mesial contact points of the first molars, terminate on the vertical lateral width lines at the first molars that were established in Step four. Mark the positions of the mesial contact points of the first molars (the ends of the brass wire) on the vertical lines representing the lateral widths of the contact points of the first molars (Fig. 3).

Step 7

Discard the brass wire. On the mandibular study cast measure the distance from the mesial contact point of a first molar to the mesial contact point of the first bicuspid on the same side. With the caliper transfer this measurement to the graph paper. Place one point of the

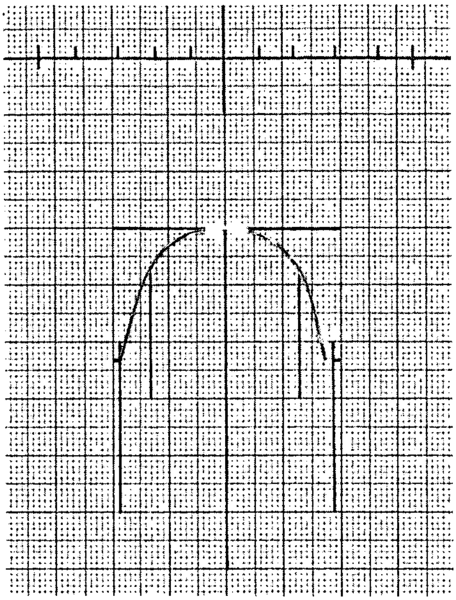

Fig. 3

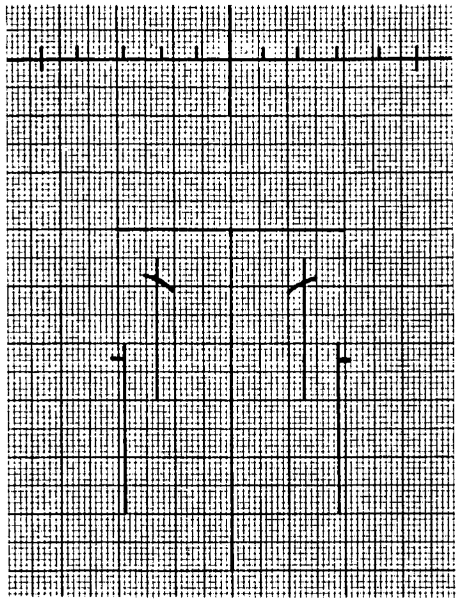

Fig. 4

caliper on the previously established lateral width marks of the mesial contact point of the first molar, and place the other point on the lateral width line of the mesial contact point of the first bicuspid. This will establish the location of the mesial contact point of the first bicuspid (Fig. 4). Locate the mesial contact point of the first bicuspid on the other side of the arch in the same way.

Step 8

Draw lines connecting the mesial contact points of the first molars to the mesial contact points of the first bicuspids of the same side. These lines establish the lateral width of the mandibular contact point arch form (Fig. 5). The fact that the lines connecting these contact points are straight lines was reported by Lasher in 1934.

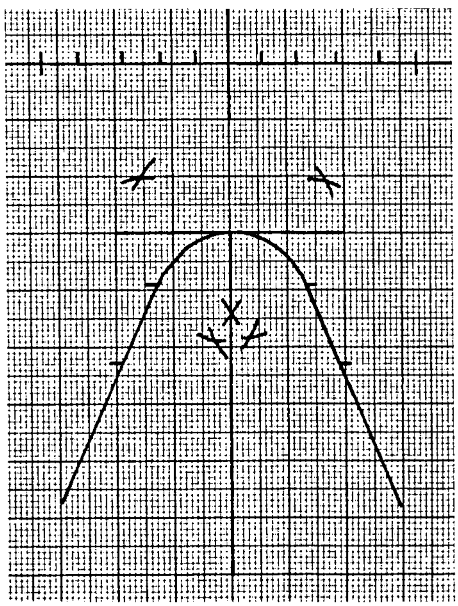

Fig. 5

Step 9

Draw a light line from the mesial contact point of one first bicuspid to the intersecting midline mark of the arch formation area. This line represents a chord of the anterior arc of the arch form. Erect a perpendicular line to the midpoint of this chord (Fig. 5). Draw another chord line from the midline mark to the mesial contact point of the other first bicuspid. Erect a perpendicular line to the midpoint of this chord.

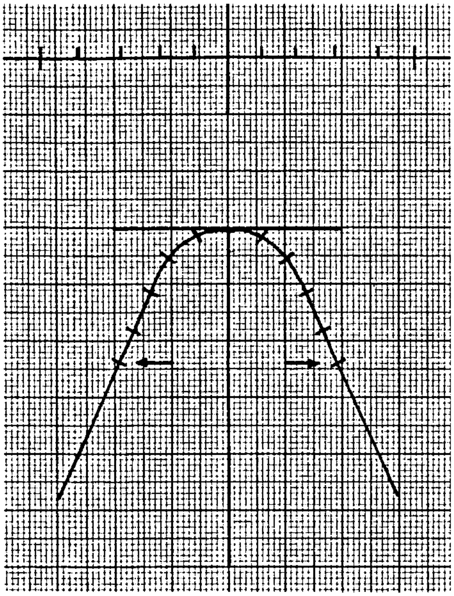

Fig. 6

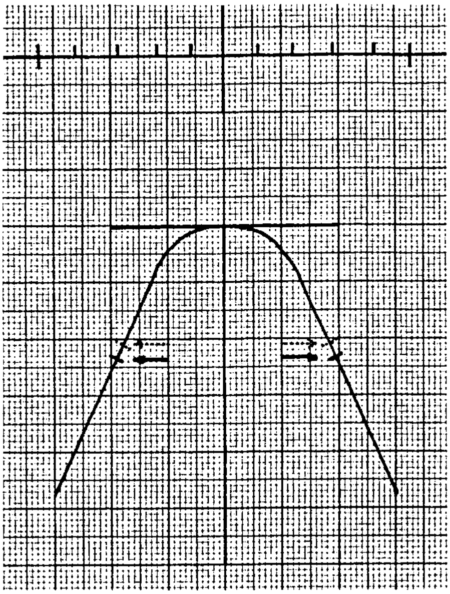

Fig. 7

Where these two perpendicular lines intersect is found the center of the anterior arc of the arch form. Form the anterior arc by using the distance from the center of the arc to a mesial contact point of a first bicuspid as a radius. Scribe the anterior arc (Fig. 5).

Lasher also established that when mandibular teeth are in good arch form, a line drawn through the contact points of the six anterior teeth forms an arc.

Step 10

Transfer the mesiodistal widths of the centrals, laterals, cuspids, first and second bicuspids from the "arch length needed" line to the arch formation area of the paper. With the calipers prick these measurements on the contact point arch form (Fig. 6). Mark the distal contact points of the second bicuspids (the same as the mesial contact points of the first molars) with arrows.

Step 11

On the mandibular study cast measure the distances from the mesial contact point of the more anterior central incisor to the mesial contact points of the first molars. Transfer these measurements to the arch chart with the calipers. Place one point of the calipers on the midpoint of the anterior arc and where the other point crosses the distal legs of the arch form, place dotted arrows. (Fig. 7).

As the constructed arch form chart represents the arch form presented by the patient, measurements made directly from one point to another can be made on the study cast and on the arch form chart.

Step 12

Measure the distance between the two arrows (Steps ten and eleven) on one side of the contact point arch form. This figure represents the arch length discrepancy for that side of the malocclusion.

Measure the distance between the two arrows on the other side of the contact point arch form. The sum of the two measurements represents the total arch length discrepancy presented in the malocclusion.

Third Procedure

Utilizing a "contact point" arch form that was related to the patient's individual arch form, contact point arch charts were constructed for each of the ten patients in this study. The arch length discrepancies derived by this method were compared with those obtained by visual inspection and the brass wire method.

Results

A review of the data collected in the first procedure, where arch length discrepancy was estimated by two different methods, revealed a wide range of variation. The information obtained by one method of assessment was quite different from information obtained by the other.

By *visual estimation,* the senior orthodontic students had a range of 5.5 millimeters for the case with the greatest disagreement. The case with the closest agreement still had a range of 2.5 millimeters.

By the method of *brass wire evaluation* the results were even less precise. A lack of agreement, represented by a range in estimation of 12.5 millimeters, was presented in one case. This range seems too large to be possible. The length of the wire was exactly as presented, however, and the exaggeration could only have been due to the student's evaluation of the "mean" arch form. This is precisely the author's point. The case that presented the smallest disagreement still evidenced a range of 5.5 millimeters.

A comparison of the *average* estimations of both methods presented a correlation within a 2 mm range, which is small.

It was impossible to find an individual estimator who was consistently close to the *average* estimations of arch length discrepancy using both methods. In fact, no estimator duplicated his original estimation using the second method.

A method for fabricating an individualized "contact point" arch chart was presented. On this chart the mesiodistal widths of the teeth anterior to the mandibular first molars were arranged in arch form. This was considered to be the arch length needed. A direct measurement across the arch was made on the study cast from the mesial contact point of the more anterior central incisor to the mesial contact point of each first molar. When these measurements were transferred to the chart the arch length available in arch form was established (*arch length needed — arch length available = arch length discrepancy*).

An assessment of arch length discrepancy made in this manner eliminated the need for speculating as to what the arch form should be.

A contact point arch form chart was constructed for each of the ten cases; the arch length discrepancy for each case was determined. These figures were compared to the *average* estimations arrived at by the visual estimation method and the *average* estimations arrived at by the brass wire evaluation method. There appeared to be a relationship. Comparing the chart figures with the average visual estimation figures, there was direct agreement in eight of the ten cases. The variance was 1.5 mm for one remaining case and two millimeters for the other. When the chart method was compared to the average brass wire figures, there was direct agreement in seven cases; the variation was 1.5 mm for the three remaining cases.

Discussion

Clinical orthodontics, in earlier days, was involved with the mechanical art of straightening teeth. Emphasis was placed on aligning the dental arches and bringing the maxillary dental arch into proper cuspal relationship with the mandibular arch. This, if accomplished, provided a good dental result. However, the clinical results of these early orthodontists, along with their tediously collected serial studies of results, began to tell a story. Many times their dental alignments lacked stability. It became evident that there must be a relationship between the positions of the teeth and the surrounding skeletal and soft tissue environment. The proper relationship of the denture to this environment had to be established.

Many serial studies of treated and untreated cases seemed to indicate a pattern in positions of stability.,[1,3,18] Men of vision began to investigate these patterns and to incorporate them into analyses based on cephalometric appraisals of many individuals.[14,20,21]

At times these men were accused of presenting a too mechanical approach to treatment. Nevertheless, the accumulation of data through serial studies, through case records of unsatisfactory orthodontic results and through years of experience, has contributed meaningful guides to judgment that cannot be denied. These analyses provide a young man entering our profession both an applicable diagnostic aid and a method of communication. "Seat of the pants" judgment must be evaluated against stated analytic norms. In short, orthodontic treatment planning has become less arbitrary.

In several of our diagnostic cephalometric analyses (Steiner and Tweed) an appraisal of the mandibular arch length discrepancy is necessary. An accurate measurement is important. A judgment between the necessity of removing permanent teeth or not removing them may very well hinge upon the number of millimeters ascribed to arch length discrepancy. The misjudging of an arch length discrepancy figure can also lead to misjudging the application of orthodontic mechanics that are necessary to affect the proper positioning of the mandibular incisors.

The orthodontic profession has been advanced as men have been able to improve diagnostic ability and mechanical technology. It is the opinion of the author that the evaluation of mandibular arch length discrepancy is not always accurate; this is graphically demonstrated by the results of this study.

The arch length discrepancy figure is integrated with other diagnostic information accurately obtained in a cephalometric evaluation of the patient. With this information the orthodontist has a basis for preparing a meaningful treatment plan. The operator may choose not to apply the diagnostic information according to specific analyses. This is his privilege. However, this decision should be based on accurately gained information. The method presented for evaluating arch length discrepancy is more reliable than the previously utilized methods.

Summary

1. A study of two methods of evaluating arch length discrepancy indicated that neither was reliable.
2. A method of constructing a patient-related contact point arch chart was presented. This chart was utilized to reliably determine arch length discrepancy.
3. Arch form was discussed. The preservation of the original lateral width of the arch form was stressed.
4. Ten students were asked to determine the arch length discrepancy of a sample of ten cases by two of the three methods of evaluation referred to in this paper: (1) by visual inspection and (2) by the brass wire evaluation method.
5. The third method, contact point arch chart, was the most accurate and reliable.

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