The Mandibular Dental Arch: Part III Buccal Expansion

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The decision as to whether or not extraction of teeth is required is perhaps the fundamental problem of orthodontic diagnosis. Contemporary practice has directed attention to the mandibular arch as the most limiting and, therefore, of first consideration for diagnosis. There are classically three quantities that need to be considered: 1) the existing tooth mass, 2) the space available for the teeth in the existing mandibular arch, and 3) the additional space that can be gained through alteration of the mandibular arch.

Little controversy exists in the situation where the space available in the existing lower arch is sufficient to accommodate the teeth. These cases are generally treated without extractions. However, such situations involve a minority of malocclusion cases. Usually a decision must be made between extraction or some alteration of the existing lower arch. There are three possible methods and/or combinations that are frequently utilized to alter the lower arch: 1) its length may be altered by changing the position of the lower incisor; 2) its width may be altered through buccal expansion of the cuspids, premolars, and molars; and 3) its length may be altered through distal movement of the molar.

A discussion of the first possibility has been treated previously. The purpose of this paper is to examine the possibility of buccal expansion in the mandibular arch as an alternative to extraction. Specifically, attention will be focused on two questions: 1) can the positions of the cuspids, premolars, and molars be altered and remain stable and 2) are there useful norms for cuspid, premolar and molar widths which can be used as a guide to enhance stability of results and minimize the need for extractions?

Literature Review

The existing orthodontic literature contains several references to our first question, "Can the positions of cuspids, premolars and molars be altered and remain stable?" Interestingly, however, it contains few references for the second question, "Are there useful norms for cuspid, premolar and molar widths which can be used as a guide to enhance stability of results?"

A recent study by Gardner and Chaconas[5] sheds some light on the first question; it utilized the Project Stability files, a random sample of treated malocclusions from Ricketts' practice with posttreatment records averaging approximately 7 years subsequent to active treatment. They noted the following in nonextraction cases: 1) Molar width increased an average of 2.04 mm during treatment and showed little relapse (2.9%). 2) Second premolars showed 1.8 mm mean expansion and 31.5% relapse. 3) First premolars averaged 2.86 mm mean expansion and 13.6% relapse. 4) Cuspids showed an average of 1.23 mm expansion and 58.5% relapse.

These results make it apparent that molars are expandable on the order of 2 mm with little relapse, while cuspids showed almost 60% relapse when expanded slightly over 1 mm. More important than averages, however, was that considerable variation in stability was noted from patient to patient; some held and some relapsed. Furthermore, there was considerable cuspid expansion (1.92 mm) in extraction cases, and the same percentage of relapse (58.8) as nonextraction. These results can be compared with the previous literature.

The stability of intermolar width is in contradiction to McCauley,[7] Litowitz,[6] Dona,[8] and Welch.[16] Walter,[14,15] however, concluded that mandibular arch width could be permanently increased. He found that, in nonextraction cases, 72% maintained an average increase of 1.8 mm intermolar width.

Cuspid relapse was shown to be an average of 58% by Gardner, which is comparable with the conclusions of Riedel[9] that these teeth cannot be permanently expanded. However, Riedel recently reported the potential of cuspids being expanded in Class II, Division 2 facial patterns. Strang[12] stated that the intercanine width of the mandibular denture is an infallible guide to muscular balance inherent to the individual and dictates the limit of denture expansion in this area. Dona[3] has also concluded that intercanine widths have a tendency to remain the same or return to the original dimensions, as have Welch[16] and Arnold.[1] Walter,[14,15] again on the expansion side, found that 62% of the nonextraction cases maintained an average increase of 2 mm of intercuspid width. Steadman[11] found intercanine width increases and decreases and could not reach a conclusion.

With regard to first premolars, it is interesting to note that there is very little to indicate that they cannot be expanded. Litowitz[6] reported that expansion between the first premolars demonstrated the least relapse tendencies and, in fact, usually showed a width gain.

It seems apparent from this brief literature review that considerable controversy exists in regard to buccal expansion; some investigators emphasize relapse, and others, stability. In summation, it seems increasingly evident that:

1) Intercuspid width bears the greatest risk in expansion; however, it may be successfully expanded in some individual cases.

2) First premolar expansion poses the greatest potential for stable change.

3) First molars might be expanded to a limited extent, but the amount of expansion demonstrated and the location on the arch result in a lesser arch length yield.

4) Some cases relapse and some do not. The literature has provided little guidance for predicting which cases could be expanded and which could not.

To provide this guidance, three independent research projects were initiated, all dealing with the concept of establishing a norm for buccal expansion. The order of their presentation is chronological, since the results of the first investigation prompted the second, and the results of the second prompted the third. To provide an overview, we summarize as follows:

From frontal and lateral headfilms, Schuler derived a norm for buccal expansion of molars based on the individual patient's measurements. After deriving a general norm for intercuspid width, he demonstrated that patients expanded past the norm showed a greater propensity toward relapse.

Taking this a step further, Lestrel then derived a norm for cuspids and first premolars (including tooth size and cephalometric measurements) which would be a function of the individual patient. It was Lestrel's objective to derive a norm for the contact point between the cuspid and the first premolar that could be used as a treatment objective, minimizing relapse.

Schulhof then tested Lestrel's individualized norm for the distal contact of the cuspids against a sample of treated cases to determine how often this quantitative norm agreed with the actual treated result, and whether there was more relapse in cases where expansion exceeded the mathematical norm.

Buccal Expansion Norms

Schuler studied buccal expansion of molars and cuspids utilizing the frontal headplate. He selected a sample which included frontal and lateral headplates and orthodontic models at beginning and end of treatment, and postretention from the Project Stability files. Seventy-two individuals (34 males and 38 females) were chosen.

Molars

The first step was to divide the cases into two groups: those whose molars expanded or remained the same after treatment, and those whose intermolar width decreased. Measurements of intermolar width were made using the frontal headfilm in each case. The fifty measurements of the Rocky Mountain Data Systems were made for each patient. Norms were calculated based upon the age, sex, race, and size of the patient (Ricketts),[8] then expressed in standard deviation units from the norm before treatment, after treatment, and postretention.

Two variables emerged as significant: one from the lateral X-ray and one from the frontal X-ray. The cases in which molar expansion held had a shorter lower face height (Fig. 1). The difference in means between the relapse group and the nonrelapse group was 3.2 degrees. The "t" value was 2.43, significant at the $p = 0.05$ significance level.

In the frontal X-ray, significant differences were not noted between the two groups before treatment. However, at the end of treatment, the measurement molar-to-jaw (Fig. 2) showed significance at the $p = 0.025$ significance level. Those cases which showed relapse of the molars had significantly less spacc between the lower molar and the JAG plane at end of treatment than those which held. The difference was 1.99 mm ($t = 2.26$). It is, consequently, possible to conclude that available

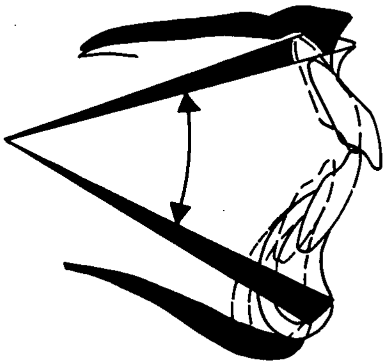

Fig. 1 The cases in which molar expansion held had a shorter lower face height. Cases with a Class II, Division 2 have this tendency toward short lower face height.

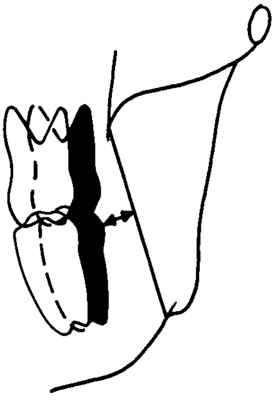

Fig. 2 At end of treatment, the measurement molar-to-jaw showed significance at the $p = 0.025$ significance level. Those cases which showed relapse of the molars had significantly less space between the lower molars and the J-AG plane at the end of treatment than those which held.

space, as defined by the molar-to-jaw distance and the facial pattern as defined by lower face height, can be used to reduce the risk of relapse when molar expansion is considered.

A norm applicable to an individual may be calculated from lower face height (mean 47°) and molar-to-jaw (mean 6 mm for an 8-year-old child), given the additional information that molar-to-jaw increases 0.5 mm per year until growth is completed, while lower face height does not change. For each four degrees lower face height is below (or above) the 47°, add (or subtract) 1 mm. And for each year age is above (or below) 8 years, add (or subtract) 0.5 mm until the age of 15 for females and 18 for males.

The final formula for the normal molar-to-jaw is then $NORM = 6.0 + (47 - LFH)/4 + .5\,(T - 8.0)$, when LFH is the patient's lower face height in degrees, and T is the age in years. The interpretation is that the patient could safely tolerate a millimeter of molar expansion for each millimeter molar-to-jaw is below the norm, calculation being made for both the left and right sides.

Cuspids

The same sample division was made to analyze cuspids between those patients who showed relapse and those who did not. The significant factor in terms of intercuspid width was the actual width measurement between the cuspid tips on the frontal headfilm at the end of treatment. It was therefore decided to investigate this factor further, and the 26 patients in the sample whose intercuspid width had increased greater than 3 mm during treatment were used for the evaluation. This sample was further divided into three groups.

(1) Those cases showing an end-of-treatment intercuspid width less than 27 mm.

(2) Those showing an intercuspid width of 27-28 mm.

(3) Those showing intercuspid width greater than 28 mm.

In these three groups the amount of change during treatment was approximately the same, about 6 mm. However, the first group showed a 2% *gain* at end of treatment, the 27-28 mm group showed a 16% loss, and the 28 mm group showed a 37% loss. Hence, if the relapse is based on averages, the fact that there *is* relapse can be misleading.

These results suggest the possibility of a norm which can be used as a guideline to minimize the chance of posttreatment relapse.

Minimizing Relapse

Gardner's work[5] has shown that the cuspids were the greatest limiting factor in arch expansion, and that the first premolars offered the greatest opportunity. Hence, the point where these two critical teeth meet might be a keystone to the amount of buccal expansion obtainable. It was Lestrel's objective to derive a norm for the contact point between the cuspid and the first premolar that might be used as a treatment objective and minimize relapse, as well as including individual factors such as tooth size and facial pattern.

Two samples were chosen. The first was a sample of 50 selected from the Foundation for Orthodontic Research normal occlusion sample, according to the criterion of least imbrication. All such cases showed less than 1 mm of crowding. This group is of special interest, since it was not selected by one orthodontist according to one criterion; each case was chosen by a different orthodontist as representing what he felt was an example of an outstanding naturally-occurring occlusion. Hence, the bias of sample selection is reduced. The second sample consisted of 67 stable results from the Project Stability files. All cases, to be considered stable, had to show less than 1 mm post-retention crowding. These were then subdivided into 24 extraction cases and 43 nonextraction cases.

A stepwise multiple regression analysis was performed to determine the dependent variable, arch width (measured at the distal contact of the cuspids), and the independent variables. (a) *incisor mass:* sum of mesiodistal diameters of the four lower incisors; (b) *mandibular width:* the distance between the left and right antegonial notches; (c) *Frankfort mandibular plane angle;* (d) *facial angle;* the angle between the facial plane and Frankfort.

The regression analysis showed incisor mass to have the greatest significance; facial angle, mandibular plane, and mandibular width were of lesser importance. The regression coefficient for incisor width was 1.0 implying a 1 mm change in intercuspid width with each millimeter of change in the sum of the four incisors.

In the normal occlusion sample, measurement at the distal of the cuspids was 28.5 mm with a standard deviation of 1.48, a small variation. In addition, the mean combined incisor width was quite small and the average facial pattern tended toward brachycephalic, as reported by Christie.[2] Dolichofacial patterns having normal occlusions were quite rare, comprising only 3% of the sample. A higher correlation between stability and facial pattern would be obtained if treated cases (with greater variability in facial patterns) were used. A normal occlusion seems to be a relatively rare circumstance requiring both small teeth and a brachyfacial face.

The results for the present treated sample showed results similar to the normal occlusion sample. However, facial pattern became more important and tooth size less important than in the normal occlusions. The stepwise multiple regression results showed that the width at the distal of the cuspids was remarkably smaller in untreated cases and in treated cases both extraction and nonextraction. In all three cases the final correlations were on the order of .7.

Finally, a formula was derived based upon these two studies which might be useful as an individualized norm for determining the ideal dimension of the lower arch at the distal contact of the cuspids. The formula is as follows:

$$
\begin{aligned}
\text{Cuspid Width} &= 28.2 \\
&+.75 \quad (\overline{21 \mid 12} - 21.2) \\
&+.3 \quad \frac{(\text{Mand. Width} - \text{Norm})}{\text{S.D.}} \\
&-.2 \quad \frac{(\text{Mand. Pl.} - \text{Norm})}{\text{S.D.}} \\
&+.15 \quad \frac{(\text{Fac. Angle} - \text{Norm})}{\text{S.D.}}
\end{aligned}
$$

This prediction formula gives a theoretical norm which can be interpreted as follows:

Given a patient's tooth size, mandibular width, mandibular plane angle, and facial angle, what would be the measurement at the distal of the mandibular cuspids in the patient with a normal or stable occlusion? The formula shows that a patient with a brachyfacial pattern, i.e., wide mandible, low mandibular plane and prognathic mandible will have a wider mandibular arch than the dolichofacial with a narrow, retrognathic mandible and a high mandibular plane angle. The norms and standard deviations used in the formula are given in Table I and are utilized in the standard Rocky Mountain Data Systems analysis.

The results of the three samples were

TABLE I
Norms for the measurements used in the prediction equations.

Measurement	Clinical Norm (At Age 9)	Rate of Change
Mandibular Width	76.1 mm	Increases 1.4 mm per year
Mandibular Plane	26°±4.5°	—1° every 3 years
Facial (Angle) Depth	87°±3°	+1° every 3 years

combined as one. The small difference in average arch width could be accounted for by the fact that the normal occlusions had smaller teeth on average, and the extraction cases had more dolichofacial patterns on average. Thus, the average differences would be explained by the independent variables in the equation.

Test of Mathematical Norm

Schulhof then tested Lestrel's individualized norm for the distal contact of the cuspids against a sample of treated cases to answer the questions, "How often will this quantitative norm agree with the actual treated result, and was there more relapse in cases where the expansion exceeded the mathematical norm?"

To test this prediction formula, 47 cases were selected from the Project Stability files using the sole criterion that the width at the distal of the cuspids be increased at least 1 mm during treatment. The question was, how often did the clinician use his clinical intuition to select the same measurement as the theoretical norm? What happened when he did? And what happened when he didn't?

Results

The sample was divided into three groups (1) the 9 cases where the end-of-treatment width was more than 1 mm less than the prediction; (2) includes those 30 cases where the end-of-treatment width at the distal of the cuspids was within 1 mm of the prediction, and (3) the 8 cases where the end-of-treatment width exceeded the prediction by at least 1 mm.

An F-test was conducted to compare the posttreatment change between groups. Pooling groups 1 and 3, the cases not following the norm, we get a sum of squares of 56.81 for 17 samples, while in the group following the norm the sum of squares was 38.16 for a sample of 30.

Thus, the F-test was:

$$\frac{56.81}{17} \div \frac{38.16}{30} = 2.63$$

which is significant at the .025 level. The group following the computer norm had less posttreatment change and was more stable than the groups which did not follow the norm.

A comparison of the three populations graphically offers some significant insights. Figure 3 shows a percentage distribution of the cases which were treated to within 1 mm of the computer norm. In this group there was the greatest stability—a full 50% showing less than 1 mm of relapse. There were no cases with more than 3 mm relapse.

The percentage distribution of the group (Fig. 4) which was overexpanded compared to the computer norms shows only half the percentage of the zero to one millimeter relapse group, and a larger percentage for a greater tendency toward relapse of 3 mm or more. This shows a general trend of greater propensity toward instability.

Group 3, having less expansion than the norm (Fig. 5), showed a bimodal description with one third of the cases

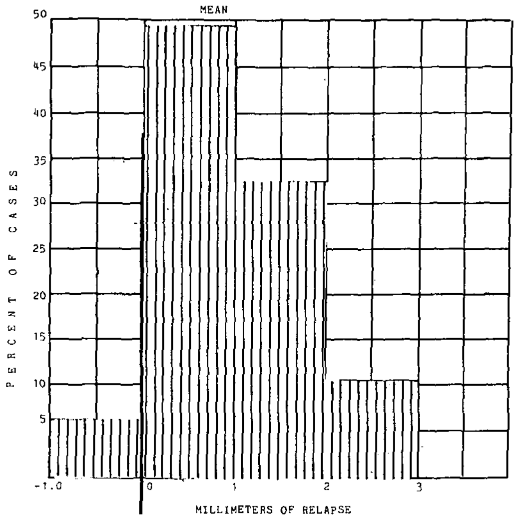

Fig. 3 Shows the distribution of relapse in the cases treated within ± 1 mm of the norm. Notice that fifty percent of these cases fall in the 0 to 1 mm relapse range. This is the most likely result.

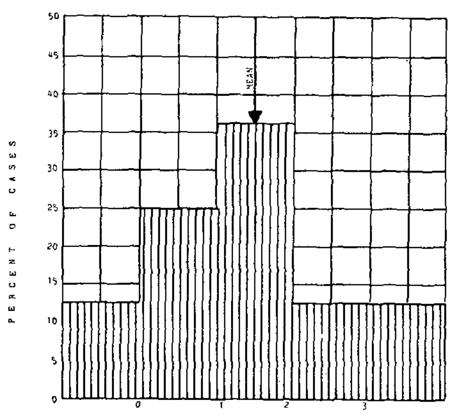

Fig. 4 Twenty percent of the cases were expanded past the computer norm. In these cases there was a greater propensity toward relapse, the mode now shifting to the 1-2 mm range.

actually increasing their arch width dimension posttreatment. In other words, these cases could have been expanded more.

As the samples were small, these results must be supplemented with further cases to render more definitive statements. However, the general tend-

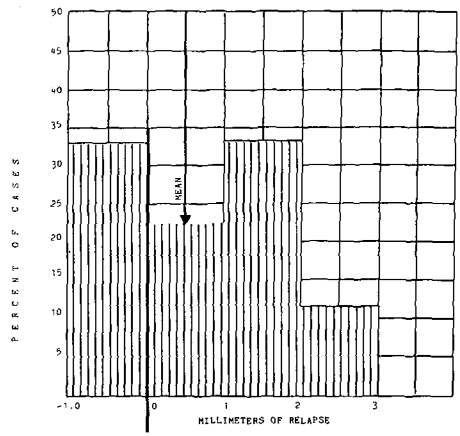

Fig. 5 Twenty percent of the cases were expanded to less than the computer norm. Here a remarkable number actually showed expansion after treatment.

ency showed greater stability when the computer norm was followed, a tendency toward relapse when the cases were overexpanded, and the possibility of greater expansion in many cases when the arch was underexpanded.

We may therefore conclude in this preliminary study, based on the computer predictions, that cases can safely be expanded to within 1 mm of the prediction without excessive relapse, but it would seem inadvisable to expand past this. Without this advance information the clinician would have to rely solely on his clinical intuition.

Summary

The tendency toward relapse in intercuspid width has been examined with those cases having final intercuspid width less than 27 mm showing significantly *less* relapse than those cases with final intercuspid width of 28 mm or more.

The point of contact between the cuspid and first premolar has been introduced as a key point on the arch, determining arch width. An individualized norm has been derived for this measurement as a function of the patient's tooth size, facial pattern, and other variables based upon stable normal occlusions in treated cases.

Those cases expanded to a dimension exceeding the norm by more than 1 mm showed a greater propensity toward relapse. The group following the norm was significantly more stable than the over- and underexpansion groups at the .025 significance level.

An individualized norm for intermolar width based upon the patient's facial pattern (using frontal and lateral X-rays) has been established. Cases showing relapse showed considerably less space between the lower molar and the JAG plane, and greater lower face height than stable cases.

The results show that the space available for the permanent dentition can be estimated in advance of treatment based on the patient's own skeletal measurements, thus minimizing unnecessary extractions, relapse, and extended treatment time due to errors in diagnosis.

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