Dental Arch Collapse In Cleft Palate

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Orthodontists have long been aware that abnormal or unbalanced muscular influences are capable of producing significant alterations of the facial skeleton and serious disturbances of the dental occlusal relationship. Over 120 years ago Rodrigues[20] called attention to the role of altered muscular function in the production of malocclusion. Undoubtedly he and others had recognized this principle some years prior to the publication of his short article in 1840. Lefoulon[17] in 1841 described irregularities of the teeth produced by repeated action of the tongue in the pronunciation of lingual syllables. In his book, published in 1843, Desirabode[8] commented on displacement of secondary incisors and canines:

"It must not be supposed that any great force is necessary for this purpose; it only requires a slight default of antagonism between two powers in the midst of which the teeth are placed, that is to say, between the lips in front and the tongue behind. Do we not perceive that, in almost all cases of hare lip, the teeth corresponding to the fissure throw themselves forward; and that the operation which corrects this deformity also replaces the teeth? This is an important fact, which goes far to enlighten us upon the choice of means proper for replacement."

The importance of muscular influence in the production or correction of malocclusion was also recognized in publications by Gaine[11] in 1856, Bridgman[4] in 1859, and Coleman[6] in 1865.

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Tomes, in 1873, ascribed virtually all irregularities of the jaws and teeth to alteration of the normal balance between the muscular forces:

". . . Along the outside of the dental arch the muscular structures of the lips and cheeks are perpetually exercising pressure perfectly symmetrically, and on the inside the tongue is with equal persistency doing the same thing. Now if we imagine a plastic material placed between the tongue and the lips, it cannot fail to be moulded into the form of a regular dental arch, and this is precisely what happens with the mobile, freshly erupted teeth; . . . There is, I believe, no such thing as a natural tendency towards the assumption of the regular form in a dental arch; the physical forces at work, namely, the lips and tongue, are amply sufficient to account for all the phenomena observed; and explanations based upon such a tendency fall, like references to 'vital force' as an explanation of physiologic phenomena into the category of mere forms of words calculated to cloak our real ignorance." 28, p. 369.

Edward Angle practiced and taught with acute awareness of these dynamic factors. In 1899 in *Dental Cosmos,* he wrote:

"The harmonious relations of the occlusal planes and dental arches are further assisted by another force, namely, muscular pressure, the tongue acting upon the inside and the lips and cheeks upon the outside. The latter, so as to keep the arches from spreading, as do the hoops upon the staves of a cask; the former prevent too great encroachment upon the oral space. I am satisfied that this muscular pressure is a far more important factor in relation to the study and correction of malocclusion than is generally recognized." 2, p. 252.

In his classic textbook, *Treatment of Malocclusion of the Teeth,* he treats the subject in somewhat more detail:

"The influence of the lips in modifying the form of the dental arches is an interesting study, and almost every case of malocclusion offers some noticeable and varying manifestation of it. In those cases where there is normal occlusion of the teeth it will be noticed that the lips and cheeks are also normal and perform their functions normally. The upper lip will be found to rest evenly in contact with the gums and upper incisors leaving, however, about one-fourth of the occlusal ends of the central incisors and laterals, and the points of the canines, to be covered by the edge of the lower lip, so that normally there is a restraining force exerted upon the upper incisors and canines by both upper and lower lips. This force is exerted automatically in response to almost every emotion, and results in maintaining the teeth in harmony with the graceful and beautiful curve of the normal individual arch." 3, p. 31.

"In cases of malocclusion strikingly characteristic abnormalities in lip function are often noticeable, leading to the suspicion that more often than is recognized the peculiarities of lip function may have been the cause of forcing the teeth into malpositions they occupy . . ." op. cit. p. 31.

". . . Doubtless, also, peculiarities of disposition, and their manifestations in movements of the lips, in many instances so modify the force exerted upon the teeth as to influence the form of the dental arches." op. cit. p. 32.

"Another striking instance of the lack of the requisite amount of force exerted by the lips and cheeks upon the external surfaces of the arch is presented in certain cases of patients suffering from cleft palate which involves the intermaxillary bones and upper lip. The lateral halves of the arch spread abnormally to a greater or less degree, in some instances the teeth of the upper jaw closing completely outside those of the lower." op. cit. p. 32.

Thus, it is seen, that from the very emergence of orthodontics as a discipline of the dental art and science, investigators and clinicians in this field have had a fine appreciation of the profound influence wielded over the jaws and teeth by the forces exerted by the oral and facial musculature.

To quote again from Angle's text:

"Normal occlusion of the teeth is maintained, first, by harmony in the sizes and relations of the dental arches through the interdependence and mutual support of the occlusal inclined planes of the teeth; and, second, by the influence of the muscles labially, buccally, and lingually." op. cit. p. 37.

Numerous authors, including Davis,[7] Brodie,[5] Fitz-Gibbon,[10] Rogers,[21] Salzmann,[23] Anderson,[1] and Moyers,[18] have continued to emphasize the potential of the muscular component in orthodontics. Additional support to this emphasis was given by Rohde[22] and Dewel.[9]

Naturally, the individual forces of occlusion cannot be considered in isolation, but rather must be recognized as an integrated dynamic complex which, under "normal" conditions, is maintained in a state of precise, though still dynamic, balance.

This brief historical resumé of the appreciation by orthodontists of muscular elements as a potent force in the development and maintenance of occlusal relationships is included because it is this force, interacting with the congenitally deficient substrata, which produces the typical deformities seen in the dental arches of patients with cleft lip and cleft palate of the more severe types. Also, the authors wish to point out that the principles involved are in no way new, but have been recognized for many decades.

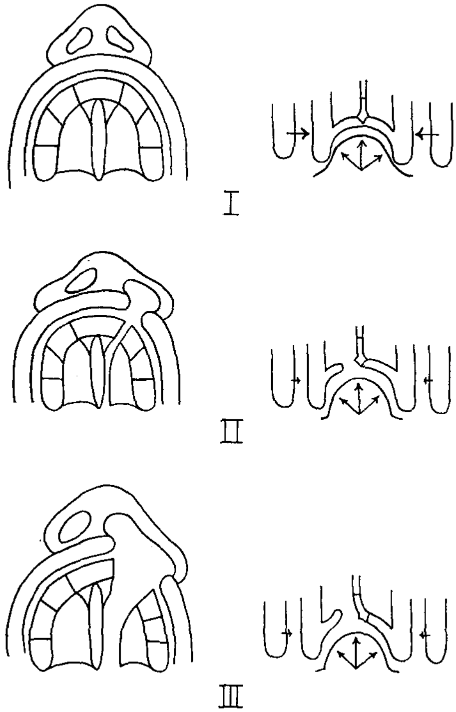
Davis[7] was one of the first to point out the importance of these principles in specific regard to the cleft lip and cleft palate problem. Thirty years ago he made an appeal for closer cooperation between plastic surgeons and orthodontists in the management of these patients. Fitz-Gibbon[10] in 1937 observed:

"A tight sphincter results from lip surgery, which in turn influences to a great extent the position of the erupting teeth. The deciduous arch as well as the permanent arch often shows the deciduous molars or bicuspids on the short side of the cleft in lingual version and the anterior teeth in torsi version",

thus summarizing the phenomenon which has since been reported by several more recent investigators: Subtelny and Brodie,[24] Pruzansky,[19] Hagerty,[13] Johnston,[16] Swanson,[26] Glass[12] Hagerty and Hill,[14] and Subtelny.[25]

For the purpose of this presentation a somewhat more detailed description of what we term "arch collapse" in the cleft palate patient is in order. The normal maxillary alveolar arch, Fig. 1, a suspended extension of the maxilla and premaxilla, gains considerable structural integrity from its classic arch configuration. In addition, it is stressed within by "flying buttresses" formed on each side by the continuity of the palatal bones, vomer, and nasal septum. These "buttresses" resist both compression and expansion of the arch. Internal stressing is further aided in resisting outside forces of compression (the muscles of the lips and cheeks) by action of the tongue beneath and within the arch. Unaltered by specific pathology or congenital malformation, these various components of force remain in balance and maintain a normal symmetrical arch which, with reasonably normal growth and eruption of the teeth, assumes a normal and functionally efficient relationship with the alveolar arch and teeth of the lower jaw.

Now let us consider the infant with the cleft lip and palate of Type III (cleft of entire soft and hard palate in continuity with unilateral cleft of the alveolus and usually of the lip, Fig. 2). Prior to repair of the lip, the external forces of compression are absent or greatly reduced, and a "keystone" of the arch is disengaged or perhaps partially absent breaking the continuity of the arch. In addition, the "flying buttress" has been removed from the short (cleft) side. Meanwhile, beginning in utero, the tongue exerts an internal force of expansion. This force

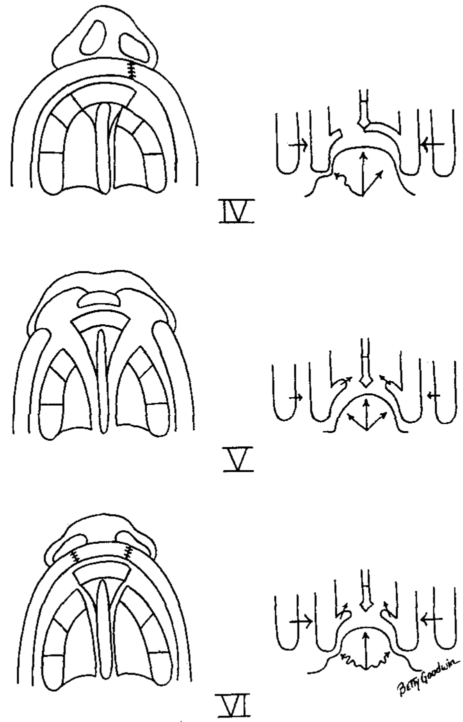


Figs. 1, 2, and 3

is virtually unopposed on the cleft side and is exerted against decreased antagonism on the noncleft side. The result is a widening of the cleft with expansion of the arch, more marked on the cleft side, together with anterior rotation of the premaxilla (Fig. 3).

Lip repair, which usually is carried out prior to four months of age and before ossification of the facial bones is complete, restores the labiobuccal sphincter with its compressive force. If the surgeon's skill and the tissue available for repair permit, this force will be restored to "normal". If either or both are deficient, it will be reflected as tightness of the lip and increased compressive force applied to the arch. In any event the expanded arch promptly yields to this muscular pressure despite the continued effort of the tongue. The alveolar process on the cleft side drifts toward the midline and the anteriorly rotated premaxilla swings back towards its normal position. If these forced migrations occur at a complementary rate and the congenital tissue deficiency is not too great, the alveolar process of the cleft side and the premaxilla may reach the normal archline at the same time and impinge, restoring the structural integrity of the arch and preventing further significant medial displacement of the short segment. If this happens, the resulting arch contour is normal or nearly so, and the prognosis for normal maxillary development with a satisfactory dental occlusal relationship is good. Unfortunately, such cases are rare. By far the more usual occurrence is for the alveolar segment on the cleft side to drift medially at a rate that exceeds the rate of posterior rotation of the premaxilla, possibly because the latter receives support from the vomer and the septum which must be overcome to effect rotation. Consequently, the short lateral segment passes the normal archline prior to the arrival of the premaxilla and, continuing to drift medially, becomes contained behind and within it (Fig. 4). In a significant number of cases there appears to be sufficient alveolar aplasia at the cleft site to preclude impingement on the normal archline irrespective of any coordination in the repositioning of the involved segments. In either event the arch is narrowed according to the degree of medial displacement or "collapse" of the alveolar segment on the cleft side.

In clefts of Type IV (complete cleft of the soft and hard palate in continuity with bilateral clefts of the alveolus and lip) the same forces and defects exert their influence, the only difference being that both alveolar segments lose the support of the palatal bones and vomer, and the premaxilla is suspended from the anterior margin of the septum, free of any alveolar attachment. Prior to repair of the lip, expansion of the arch may be profound and the premaxilla may be displaced far anteriorly and rotated superiorly (Fig. 5). Lip repair can result in collapse of either side and not infrequently produces bilateral collapse with the alveolar segments meeting on the midline behind the protruding premaxilla, "locking it out" of the arch (Fig. 6).



Figs. 4, 5 and 6

As pointed out before, this sequence of events has been observed and described in more or less detail by numerous authors.

This particular study is concerned with measurements of dental arch areas as indicators of collapse in postoperative cleft palate patients.

Material

Material for this investigation consisted of the dental study models of 105 postoperative cleft palate patients who had been examined since April 1956. Except for the elimination of four patients whose dentition was inadequate for the methods used, the series was *consecutive* and *unselected*. The distribution of subjects by type of cleft is seen in Table 1. The average age of the subjects at the time the study models were secured was 15 years. The ages ranged from 5 to 50 years. There were forty-five females and fifty-eight males. Seventeen of the patients were negro and the remainder white.

Orthodontic examination disclosed crossbite in 30 per cent of the subjects having cleft Types I and II. Crossbite was also seen in the cleft side in 74 per cent of the subjects with Type III clefts. Bilateral crossbite was found in 56 per cent of the Type IV cleft group but no unilateral crossbite was seen in any subject with Type IV cleft.

The control material consisted of dental study models of 55 white subjects ranging in age from 7 years 6 months to 32 years with an average of 11 years 6 months. There were twenty-one males and thirty-four females. This group was taken from the private orthodontic practice of one of the authors (C.E.C.). The members of this group presented occlusal abnormalities of minor degree but none had any type of cleft deformity. In each control case the pretreatment model was used.

Method

By means of a standardized photographic technique and the rolling disc planimeter, the palatal area was determined for each member of both groups as described later. This area was divided into anterior and posterior quadrants along the midline and corresponding segments were compared.

TABLE 1
DISTRIBUTION BY CLEFT TYPE

Palate Cleft	Lip Cleft	Number Cases
Submucous	None	2
Type I	None	13
Type II	None	17
Type III	Unilateral	57
Type IV	Bilateral	16
	Total	105

Type I represents cleft of the soft palate; Type II cleft of the soft and hard palate; Type III cleft of the entire palate and alveolar ridge unilateral; and Type IV cleft of the entire palate and alveolar ridge, bilateral.

Analysis of the palatal area provided an objective numerical measurement of palatal asymmetry. The control series was studied to determine the degree of palatal asymmetry reflected by this method in a group free of cleft deformities. Since all members of the control group showed occlusal abnormalities, it is possible that this "baseline" asymmetry is somewhat greater than would be found in a random sampling of noncleft cases.

Patients with submucous clefts, clefts of Type I, and of Type II, were analyzed by this method to determine palatal asymmetry as compared with the control group. In Type III patients with associated cleft lip, quadrants on the cleft side were compared with their opposites on the noncleft side and analyzed for "collapse" in terms of the area differences.

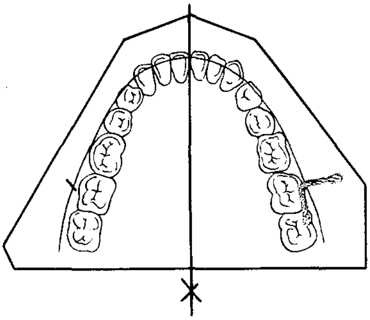
The Type IV cases presented a somewhat different problem because there was no "normal" side which could be used as a reference to determine the amount of collapse. Accordingly, an attempt was made to determine a normal area ratio between the upper and lower arches in the control group by measuring the area contained within corresponding anterior segments of the upper and lower arches forward of a perpendicular frontal plane passing four centimeters posterior to a point between the mandibular central incisors in centric occlusion. Similar measurements were then made in the Type IV cases in the study groups. Discrepancies in the upper arch to lower arch area ratios were analyzed for reflection of collapse of the lateral segments. In outlining the upper arch margins in the Type IV cases the anterior border of the arch was determined by extrapolation of the curves formed by the lateral sections without regard to the position of the premaxilla. This was done because there were several cases in both groups with marked anterior displacement of the premaxilla. The displacement produced discrepancies in anterior arch area that were in no way related to collapse of the lateral sections which is the subject of this study.

Technique

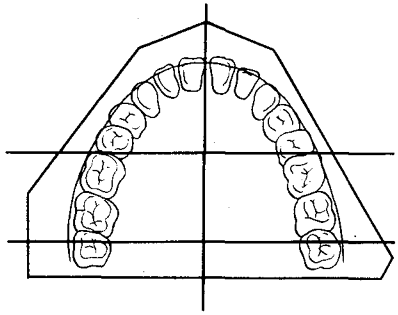
Each dental study model was trimmed in centric occlusion with the base of each model-half parallel to the occlusal plane. Each model-half was then separately photographed at a fixed distance with the center of the occlusal plane directly in front of the point of focus. The photographs were printed on Kodak Resisto Rapid paper to eliminate distortion in processing. The recommended processing and air drying produced consistently good prints on which the outlines of the alveolar processes and the dentition could be clearly seen.

On the mandibular half of each photograph the buccal and labial borders of the alveolar processes were outlined. The interspace between the lower central incisors at the lingual gingival line superior to the genial tubercle (the most consistent "midline" point identifiable in our experience) was used as a center and from it arcs were struck to cross the buccal outline of the mandibular alveolar process on each side. The paired crossing points were then used as centers to strike additional intersecting arcs. These arcs were of identical radius for each pair of cross-points and intersected at points within and equidistant from the external borders of the mandibular arch. Thus a "functional midline" on the occlusal plane was determined for the lower arch (Fig. 7).

The buccal and labial border of the maxillary alveolar arch was then outlined on the photograph of the upper model-half. By using a bright x-ray viewbox and two or more corresponding points on each model-half for orientation (the models were trimmed in occlusion so corresponding corners of the model bases could be used for such orientation) the photographs could be put face to face and placed "in occlusion". The functional midline could then be transferred from the lower arch to the upper by pricking through a series of points with a sharp instrument. After the midline was transferred to the photograph of the upper arch, a posterior transverse line, perpendicular to the midline, was drawn through the area of maximal arch-width in the molar region. A second parallel transverse line was drawn across the arch midway between this line and the anterior extent of the midline. Thus the upper arch was divided into four quadrants, one anterior and one posterior on each side of the derived midline transferred from the lower jaw (Fig. 8). The area of each quadrant was then determined with the rolling disc planimeter. Each step was carried out by each of two separate investigators and the correlation of the two sets of data approached unity. The means of the two sets of data were



DETERMINATION OF THE MIDLINE OF THE MANDIBULAR ARCH



TRANSFERAL OF THE MANDIBULAR MIDLINE TO THE MAXILLARY PHOTOGRAPH AND DIVISION INTO QUADRANTS

Figs. 7 and 8

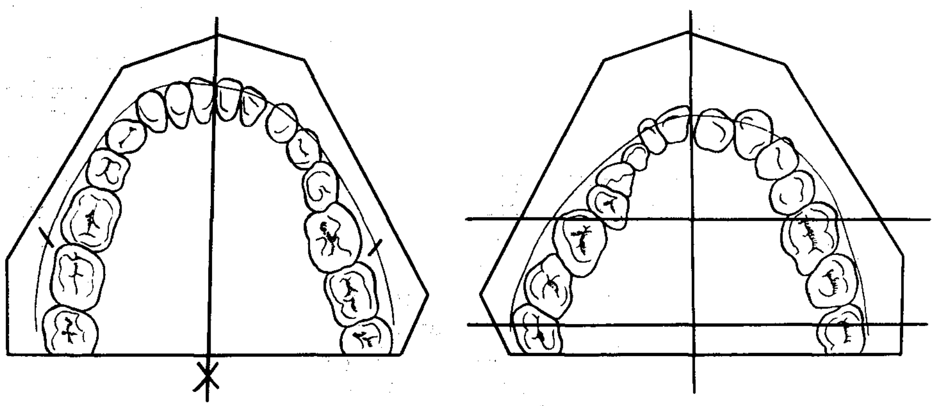
used in the final analysis. Dental arch collapse as reflected by asymmetry of the anterior quadrants is depicted schematically in Figure 9.

Results

Scattergrams were made of the palatal area measurements of the submucous, Type I, Type II, Type III and Type IV postoperative clefts. No evidence of arch collapse was found in the Type I and Type II cleft groups.

A scattergram of the anterior quadrant areas of the Type III postoperative group is seen in Figure 10. This showed a marked decrease of the anterior quadrant on the cleft side as compared with the noncleft. A similar scattergram of the control group of normals (Fig. 11) revealed no such differences of areas on either side of the midline.

Identical studies were carried out with regard to comparison of the areas of the posterior quadrants of the Type III postoperative cleft palate patients. The marked differences as seen in the anterior quadrant area measurements



DIAGRAMMATIC SKETCH OF TYPE III CLEFT PALATE DEMONSTRATING ARCH COLLAPSE

Fig. 9

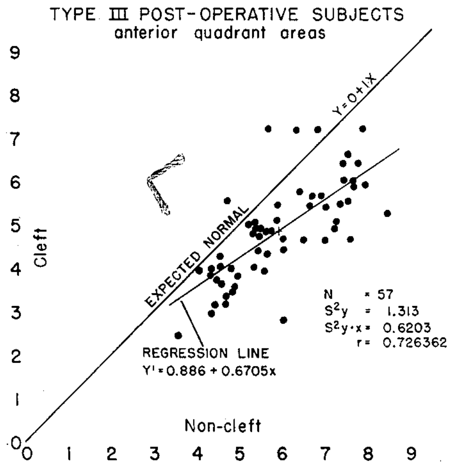


Fig. 10

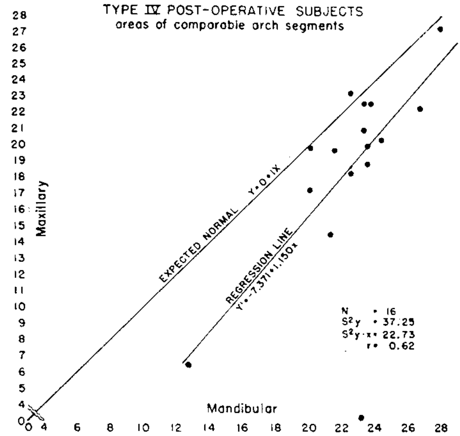


Fig. 12

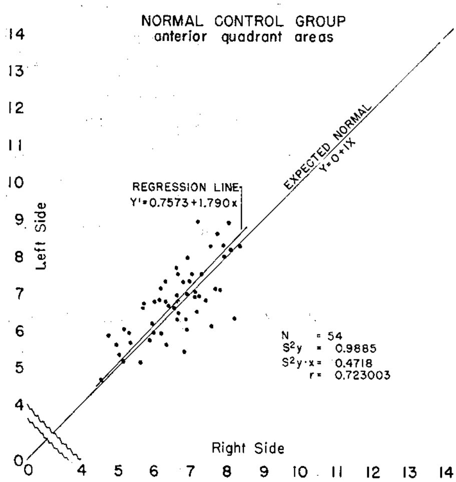


Fig. 11

were not evident. The regression equations computed from the data on posterior quadrants were $y' = 0.57 + 0.94X$ for the cleft group and $y' = 2.072 + 0.81X$ for the controls.

Figure 12 is a scattergram of the corresponding areas of the maxillary and mandibular arches of the Type IV postoperative clefts. The distribution of the control measurements would indicate little or no relationship between the maxillary and mandibular areas. It was clearly evident, however, that the maxillary areas were greater than the mandibular areas in a much larger proportion of the control group than in the postoperative Type IV group. In only one of the fourteen Type IV postoperative groups was the maxillary area larger than the mandibular, whereas in the normals 50 of 55 cases showed larger maxillary areas.

Discussion

The technique used in this study permits the introduction of certain subjective differences, for example, in tracing the outline of the gingiva or in establishing the midline of the maxillary arch from the mandibular arch. Nevertheless, after considering many alternatives, it turned out to be the most consistent and accurate means of measuring dental arch areas and, despite the opportunities for subjective differences, two separate investigators arrived at almost identical results.

It is evident from evaluation of the results that there is a significant decrease in palatal area of the anterior quadrants on the cleft sides as compared with the noncleft in the Type

III cases indicating a significant and profound dental arch collapse in this area. Such a collapse was not seen on examination of the posterior arch quadrants in this type of cleft defect.

With increasing size of the palatal areas (usually related to age) the area of the anterior quadrant on the cleft side in the Type III patients is seen to become disproportionately less than that of the noncleft side. This is depicted in the scattergram in Figure 10 and in the regression line having a slope of 0.67. The causes for this relatively increasing collapse of the dental arch on the cleft side in this group of patients are not readily apparent. As a result of this finding, however, it was not appropriate to express the amount of dental arch collapse, as represented by area measurements, in per cent or degrees.

In the Type IV cases measurement of related superimposed anterior palatal areas revealed a deficiency of the maxillary area in all cases as compared with the mandibular. The same technique used with the normals resulted in quite the reverse result. However, in the normals, aside from the fact that the maxillary area was almost invariably larger than the mandibular, there was no relationship in their respective sizes. The range of mandibular area was much smaller than that of the maxillary area.

Conclusions

1. No dental arch collapse was demonstrated in submucous, Type I, or Type II postoperative cleft palate patients.
2. Dental arch collapse, as indicated by area measurement of the anterior palatal quadrants, was seen in almost all Type III postoperative patients on the cleft side. With increasing palatal size there is an absolute increase in asymmetry between these quadrants, but the relation between cleft and noncleft remains the same as shown by the linear regression equation.
3. Dental arch collapse, as indicated by area measurements of related superimposed anterior arch segments, was seen in all Type IV postoperative patients.
4. Since dental arch collapse is a frequent accompaniment of the more severe types of palatal clefts, efforts should be made to prevent it.

Part II: The Unoperated Cleft Palate Patient

A group of thirty-five subjects with unoperated cleft palates was studied using the same methods and techniques as those described earlier in the report of dental arch collapse in postoperative subjects. The group was distributed according to cleft type as follows:

Submucous cleft	4
Type I	4
Type II	6
Type III	15
Type IV	6
Total	35

The average age at time of lip repair of the Type III group, all of whom had complete clefts, was 12 months. All six of the Type IV subjects had complete bilateral lip clefts, the majority of which were closed by nine months of age.

Results

Examination of the submucous, Type I and Type II unoperated cleft palate subjects revealed no significant asymmetry of their palatal halves.

Figure 13 is a scattergram representing anterior quadrant area measurements in the Type III unoperated cleft palate patients. As indicated by the regression equation, $y' = 2.135 + 0.4992X$, it is seen that the degree of

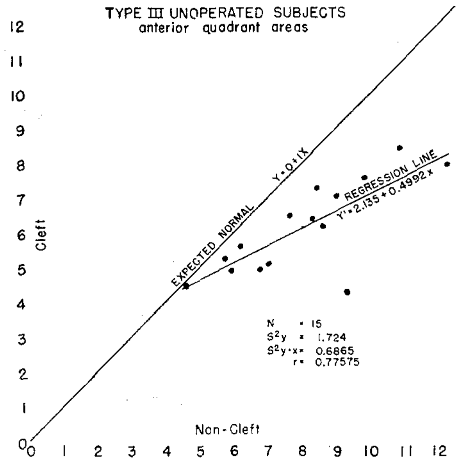


Fig. 13

collapse on the cleft side in this group of fifteen unoperated cleft palate patients was greater than that in the postoperative subjects, $y' = 0.886 + .6705X$ (Figure 10).

Figure 14 is a scattergram showing the relationship of comparable areas of the anterior jaws in the Type IV unoperated subjects. The regression equation here was $y' = 17.892 + 1.993X$ as compared with $y' = 7.371 + 1.150X$ for the postoperative subjects (Figure 12).

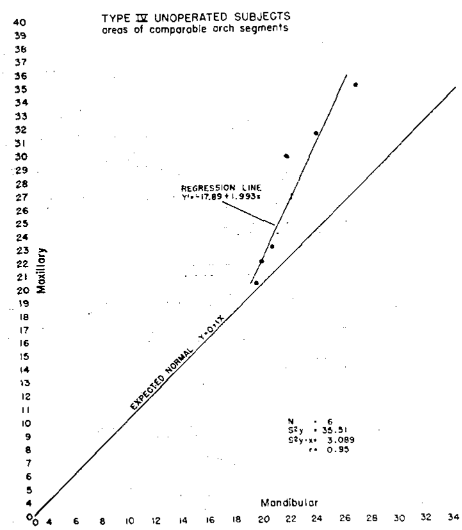


Fig. 14

Discussion

Dental arch collapse in fifteen subjects with unilateral defect who had had lip surgery but no palatal surgery was seen to be more severe than that found in postoperative cleft palate subjects. The asymmetry appeared to increase with the increasing size of the palate.

In this group of patients the lip was closed at a relatively late age, 12 months, in comparison to the other two groups (three months). One might conjecture that such delayed lip closure would be associated with a greater widening of the cleft and its relative fixation in that position with calcification and ossification of the midfacial bones. Perhaps such changes did take place but, after lip repair, the constricting muscular forces were sufficient to overcome them. Since the collapse seen in this group was more severe than that in the postoperative cleft palate subjects, one might ascribe to palatal surgery a possible supporting function in limiting arch collapse. In any case, lip surgery, even when deferred to a later age as in these subjects, appears to be the primary mechanism of medial displacement of the arch segment on the cleft side. The type of lip closure, of course, plays an important role with a tight constricting force producing more rapid and advanced collapse than a less tight one. In the prevention of arch collapse it is currently difficult to state the relative importance of the roles played by a supporting appliance such as a palatal bar or by loose lip repair.[13]

In examination of the six Type IV unoperated cleft palate subjects, the values of the areas of comparable arch segments were seen to fall into a more normal distribution than that for the postoperative cleft palate subjects. In all subjects the maxillary area was greater than the mandibular area, and the range in size of the mandibular segment remained much less than that of the maxillary segment. As in the normals, it is seen that the mandibular area is relatively consistent, but the related maxillary areas showed a wide variation. Although the unoperated Type IV cases number but six they all show this difference from the postoperative subjects. This may be the result of the supporting effect of the premaxilla between the anterior alveolar segments, but on the other hand might also be explained by the more extensive surgery for palatal closure required on the Type IV cases with resulting interference to the growth rates of the premaxillary segment and anterior palatal areas.

Conclusions

Dental arch collapse in fifteen unoperated unilateral complete cleft palate patients (lip repaired at age 12 months) was found to be more marked than that found in a group of similar patients following both palatal and lip surgery. On the other hand, in six bilateral cleft lip and palate patients who had had lip repair only, and generally earlier, the arch contour approached the normal much more closely than a similar group who had had both lip and palatal surgery.

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