Forces Produced By Rapid Maxillary Expansion

III. Forces Present During Retention

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Introduction

Rapid mechanical maxillary expansion procedures as presently employed utilize large loads designed to produce a maximal skeletal repositioning with a minimum of individual tooth movement. A fundamental similarity exists, however, between these procedures and the more conventional orthodontic procedures designed to produce maximum tooth movement. In both instances the displacement of a skeletal part (individual tooth or maxillary half) produces a cellular response at an articulation (periodontal ligament or maxillary suture). The magnitude of the load is important only insofar as greater loads are required to overcome skeletal resistance in the displacement of the maxillary halves than in the displacement of individual teeth. It should not be construed, however, that the one treatment may be substituted for the other as each has its specific indications.

The dentition erupts into an environment completely dominated by a muscular system which dictates individual tooth position. In patients demonstrating severe maxillary constriction, the conventional slow expansion procedures only encourage relapse by tipping the teeth beyond the boundaries dictated by the surrounding musculature. As the rationale governing rapid maxillary expansion is orthopedic rather than orthodontic in nature, the teeth themselves are displaced only slightly in their alveoli while the maxillary bones with the attached musculature are separated. Thus, the teeth occupy the same positions over basal bone and will be subject to relatively the same musculature influences.

Heretofore, appliance activation has been determined on a highly empirical basis and only recently has a quantitative appraisal of some of the forces produced during rapid maxillary expansion been presented.[10] At present there is no information available concerning the duration of these forces and their fate during the retention phase of treatment.

During the evolvement of rapid expansion techniques over the past century, a conflicting array of information has been directed at insuring against the relapse of the involved skeletal and dental structures. The fact that the void created by the opening of the midpalatal suture is subsequently filled with new bone has been suggested as the primary indication of when permanency of the treatment is assured.[1,2,6,13] Suggestions as to the length of time fixed retention should be maintained include: "until the bicuspids erupt into occlusion",[16] "until the teeth are in their upright positions with their buccal cusps

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interlocked",[7] three to four weeks,[2,5] four to six weeks,[13] two months,[12] three months,[3,6,15] one to two years,[11] and permanently. It has also been suggested that at the conclusion of the fixed retention period a removable acrylic palatal plate be used continuously for additional retention.[3,5,6]

This study is part of a program undertaken at the University of Minnesota to evaluate the rapid maxillary expansion procedure. Its primary purpose was to quantitatively investigate the forces present during the retention phase of treatment and evaluate this information with regard to the optimal duration retention should be maintained. Additional data regarding the forces produced during rapid maxillary expansion procedures were also noted and reported.

Methods and Materials

This investigation was conducted on four patients, three male and one female, referred to as *A, B, C* and *D* ranging in age from eleven years, six months to fifteen years, six months. All patients demonstrated bilateral dental crossbites with some degree of maxillary constriction and varied from the mixed to the permanent dentition in dental development.

The rapid expansion appliances consisted basically of 1) orthodontic bands fitted to selected teeth in the maxillary buccal quadrants, 2) an expansion screw positioned in the midline, 3) acrylic connecting the bands in one quadrant and one-half of the expansion screw and 4) a force-measuring dynamometer attaching the bands in the other quadrant to the other half of the expansion screw. The details of the construction of this appliance have been previously described.[9] In this study, however, in order to obviate the previously reported waterproofing difficulties, the strain gauges were bonded directly on to the dynamometer surface

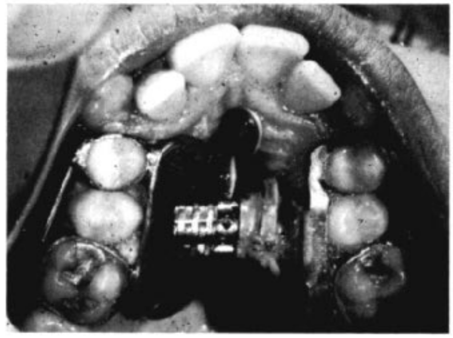

Figure 1 The expansion appliance with incorporated force measuring dynamometer in the mouth. Appliance leads tucked away in the space between the expansion screw and palate.

with an epoxy resin followed by a coating of waterproofing media. The final appliances were connected to a Baldwin strain-indicating unit, calibrated, and a zero load established prior to cementation in the mouth. The appliances performed satisfactorily in the mouth for periods up to three months.

In most instances a twice-daily activation schedule (one-fourth revolution of the expansion screw per activation) was initially followed, but this was commonly modified to produce loads not in excess of the proportional limit of the dynamometer. During the expansion phase of treatment the patients were observed daily and one activation was often made at this time. During the retention phase the expansion screw was stabilized with brass ligature wire and data were periodically recorded. At the conclusion of all appointments the lead wires were disconnected, ensheathed in vinyl tubing and placed between the expansion screw and the palate as shown in Figure 1.

All patients were treated with this appliance until sufficient expansion was achieved to clinically correct the crossbite occlusion. Each appliance was utilized as a retainer until the loads recorded decayed to a level considered negligible in relapse potential at which time the appliance was removed. No other retaining appliances were used. Diagnostic models were also taken at the time of appliance removal and both ten and thirty days later.

Results

Expansion Phase

The maximum load produced by any single activation occurred immediately at the time of appliance activation and began to dissipate soon thereafter. At the onset of treatment the loads produced by an activation were frequently dissipated in the succeeding twelve hour period. Soon, however, this was not the case and accumulated residual loads rapidly resulted in the production of higher total loads. These increased loads were not due to any increase in the net load produced by the individual activations, but rather were due to the progressive failure of preceding loads to fully dissipate in the period between activations. In all patients the increment of load produced by a single activation remained quite consistent throughout treatment irrespective of the total load on the appliance at the time of activation (Figs. 2 and 3).

An apparent age differential was noted in the time required to dissipate loads produced by the appliance. Younger patients dissipated the loads produced by a twice-daily activation schedule for a longer period of treatment before accumulating sufficient residual loads to produce values capable of threatening dynamometer distortion. In the oldest patient, *D* a female aged fifteen and one-half, residual loads accumulated so rapidly that a once daily schedule was adopted on the fourth day of treatment. During the later stages of treatment it became necessary to revert to a once-daily activation schedule in the youngest patient, *C*, as well. The loads produced

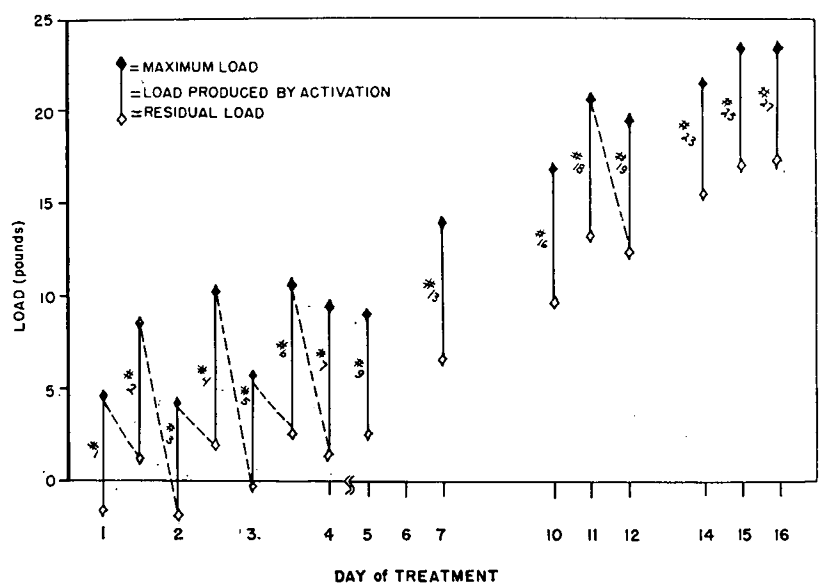

Figure 2. Summary of forces produced during activation of patient *A*, (13 yr. M). This is typical of the younger patients (*A*, *B*, *C*) treated in this study. Note the constancy of the increment of load produced by each activation. Also note the gradual accumulation of residual load after the first two days of treatment.

by once-daily activation of the appliance completely decayed during a twenty-four hour period in the younger patients, but even this schedule accumulated residual loads in the older patient. This residual load amounted to between five and twenty-five percent of the load produced by the activation; consequently, a higher total load level was produced by a lesser number of activations in the older patient.

Separation of the central incisors occurred between the ninth and twelfth activations in all patients and was not accompanied by any increased subjective symptoms or drop in recorded load. Variable pressure sensations around the teeth, under the eyes and at the nasal area were reported at the time of activation but disappeared rapidly without discomfort. Transient soreness was reported in the teeth as the occlusion was changing from the crossbite to a more normal buccolingual relationship. This soreness disappeared, however, as soon as the crossbite was corrected.

In patient *A*, thirteen years, twenty-nine activations were made over a period of seventeen days with the first residual loads evident on the fourth day and gradually accumulating to produce a maximum load of 23.3 pounds on the fifteenth day of treatment. A twice-daily activation schedule was maintained throughout treatment, except for day eleven when only one activation was made, resulting in a total expansion of 7.5 mm in intermolar width and 7.0 mm in interbicuspid width.

In patient *B*, twelve and one-half, the appliance was activated nineteen times over the first thirteen days with the first residual load evident on the third day of treatment and producing a maximum load of 16.6 pounds on the seventh day. During the course of active expansion it was necessary to remove the appliance for a period of four days to reposition the lead wires due to a faulty connection. A relapse of 2.0 mm was noted in transpalatal interbicuspid and intermolar width during the time the appliance was out of the mouth. The expansion screw was backed off eight one-fourth revolutions to compensate for the amount of relapse, re-

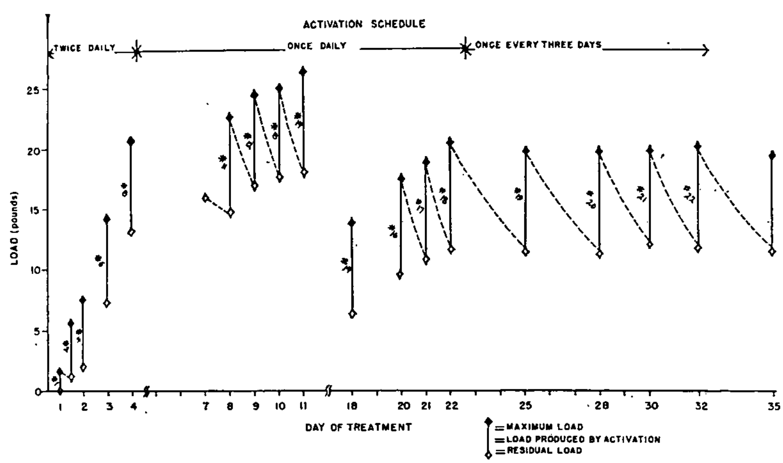

Figure 3 Summary of forces produced during activation of the older patient *D*, (15½ yr. F). Note the constancy of the increment of load produced by each activation. Notice the rapid accumulation of forces on a twice daily activation schedule followed for the first four days of treatment. Also note that a once daily schedule accumulated residual loads in this patient. Compare with Figure 2.

cemented and an additional thirteen activations were made over the next five days. A twice-daily activation schedule was maintained throughout treatment resulting in a total expansion of 5.0 mm in intermolar width and 5.3 mm in interbicuspid width.

In patient *C,* twenty-one activations were made over a period of eighteen days producing residual loads early in treatment which gradually accumulated to result in a maximum load of 24.5 pounds on the eighteenth day. A twice-daily activation schedule was maintained until day eleven, when a schedule of one activation per day was adopted resulting in a total expansion of 5.8 mm in intermolar width and 5.8 mm in interbicuspid width.

Patient *D* was activated nineteen times over the first seventeen days. A twice-daily activation schedule was used initially but accumulating residual loads on the second day necessitated adoption of a once-daily schedule on the fourth day of treatment. Even this schedule accumulated residual loads and was modified to one activation every other day to avoid production of excessive loads. Despite this precaution, the proportional limit of the dynamometer was exceeded and it was necessary to remove the appliance from the mouth for recalibration. At the time of appliance removal, an estimated 34.8 pounds of expansion force was present. The immediate consequence of this premature appliance removal was dizziness and the feeling of heavy pressure at the bridge of the nose, under the eyes and generally throughout the face. Blanching of the soft tissues overlying these areas as well as between the central incisors was observed. These symptoms of vertigo and pressure continued over the nineteen hours the appliance was out of the mouth and a measured relapse of 1.5 mm in transpalatal dimension was noted. The expansion screw was reversed six one-fourth revolutions, recemented and an additional nine activations were made over the next eighteen days. Upon recementation of the appliance, with a recorded 7.9 pounds of expansion force, all previously described symptoms disappeared. A total expansion of 6.2 mm in transpalatal intermolar width and 6.4 mm in interbicuspid width was achieved.

Retention Phase

Residual loads were demonstrated at the termination of appliance activation in all four patients. These loads dissipated within approximately six weeks with the greatest decrease in load occurring during the first week of retention and in succeedingly smaller increments from week to week thereafter (Fig. 4).

Postretention Phase

A comparison of measurements obtained prior to and immediately after appliance removal revealed no decrease in transpalatal interbicuspid and intermolar dimension. Measurements taken from the study casts made ten and thirty days postretention revealed a slight variable decrease in interbicuspid and intermolar dimension; however, at no time was the integrity of the crossbite correction jeopardized.

Discussion

Considerable clinical and experimental data have been accumulating in recent years concerning rapid maxillary expansion procedures. No evidence has been found to suggest that the procedure should not be included in the armamentarium of the orthodontist, but because of its unusual approach to the correction of skeletal defects it must be exhaustively investigated.

Activation of the expansion screw produces a lateral load which is immediately directed against the teeth. As soon as the expansion exceeds the width of the periodontal ligament, the facial skeleton acts as a unit in offering

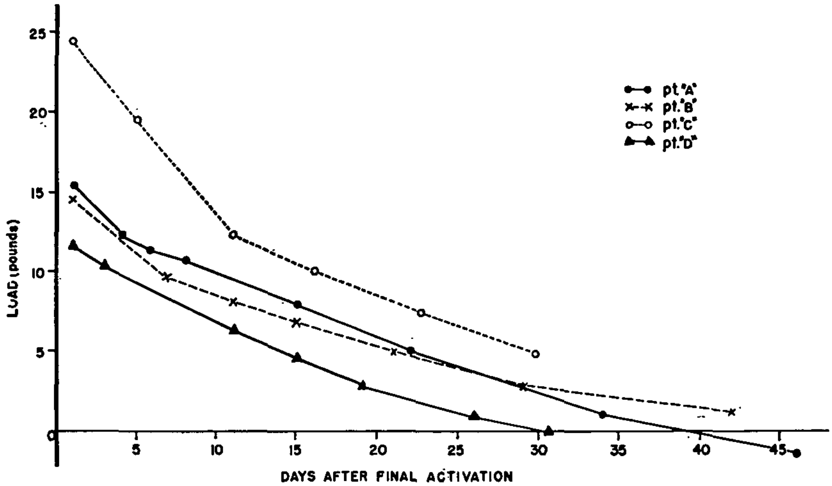

Figure 4 Retention phase of treatment. Loads recorded from the time of the last activation until the appliances were removed from the mouth. Note that the rate of load decay is essentially the same in all patients. Retention on patient *C* was continued for thirty-nine days, however, due to a sudden break in the gauge circuitry no data were recorded after day thirty.

resistance to the expansion. Therefore, it may be reasonably assumed that the amount of load measured by the strain-indicating system was representative of the resistance of the facial skeleton. The load produced by any activation, if the facial skeleton does not respond by immediate movement, is stored as potential energy in the appliance itself. The fact that the loads produced by a single activation were relatively constant in all patients indicates that the skeletal structures do not move immediately in response to an activation, but that a slight time lag exists. The subsequent decrease in load following the activation can be explained by the movement of the maxillary segments and consequent separation of the central incisors which was observed in all patients. This decrease in load did not occur uniformly but began seconds after the activation at a rapid rate (30-50 percent of the increment produced by the activation dissipated within the first fifteen minutes) and slowed progressively over a twenty-four hour period. The progressive failure of succeeding loads to fully dissipate in a similar twelve or twenty-four hour period, with resultant accumulation of residual loads, was interpreted as a gradual increase in skeletal resistance.

The hypothesis that the facial skeleton increases its resistance to expansion significantly with increasing age and maturity[8,10,14] was supported by the fact that the oldest patient, *D*, produced a higher total load over a lesser number of activations, required more time to dissipate the loads produced by the expansion procedure and accrued higher residual loads than the other three patients. Patient *C*, on the other hand, in the mixed dentition stage of dental development, responded to treatment in much the same fashion as did patients *A* and *B* of a similar age suggesting that dental development and skeletal maturation are not necessarily interrelated.

A discussion of the loads produced during activation and their subsequent decay raises the question of whether an optimal load value capable of producing successful clinical results exists. Is

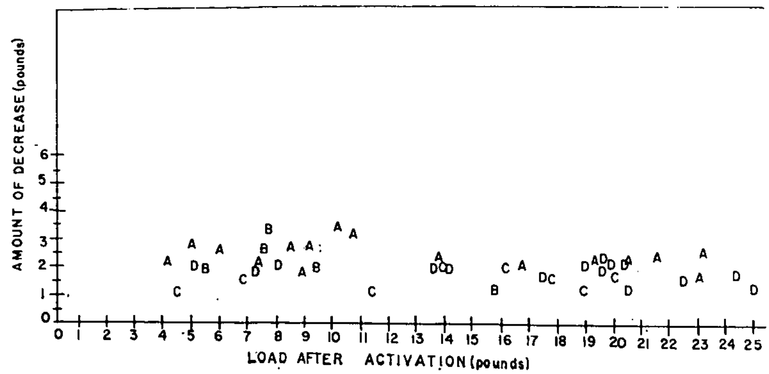

Figure 5 The amount of load decay that occurred in the five minutes immediately following an activation represented graphically against the total load present on the appliance at that particular time. Notice that the decay rate is not significantly influenced by the total load on the appliance.

it necessary to attain the high load levels commonly produced by current popular activation schedules? The rate of load decay is proposed as representative of the movement of the skeletal structures. Since it has been demonstrated that the load decay rate is not influenced by the total amount of load present on the appliance (Fig. 5), it seems reasonable that the optimum rate of activation would be one whereby additional loads would be added at close to the same rate that the facial skeleton can respond by physiological movement. A twice-daily activation schedule, most commonly proposed in the literature, was shown to produce residual loads in all patients early in treatment. In accord with the aforementioned hypothesis, a suggested rate of activation for the younger patients described in this study would be twice daily for the first four to five days followed by one activation per day throughout the balance of treatment. In the oldest patient, due to the increased skeletal resistance, this schedule would be further modified to two activations per day for the first two days, one activation daily for the next five to seven days, and one activation every other day to complete treatment.

The role of the midpalatal suture itself in offering resistance to maxillary expansion is questionable. Based on the lack of significant changes in load levels present at the time of midpalatal suture opening (a drop in load would be expected) observed in this and earlier studies, as well as reported activity at contiguous maxillary sutures, it follows that the major resistance to rapid maxillary expansion must lie in the remainder of the maxillary articulations.[10] Therefore, the retention of rapid maxillary expansion cases would not necessarily depend on the presence of bone in the opened midpalatal suture, but rather on the creation of a stable relationship at the articulations of the maxilla and the other bones of the facial skeleton. As long as forces remain at adjacent maxillary articulations, there is no reason to assume that bone deposited within the midpalatal void would not be resorbed in the reestablishment of a physiologic equilibrium.

The residual loads acting upon the appliance at the end of the expansion phase of treatment were shown to entirely dissipate within a five to seven week period (Fig. 4). As the expansion screw was stabilized with brass ligature wire, only two possibilities exist to explain the decrease in load (release of potential energy) during fixed retention: 1) further displacement of the maxillary segments can occur or 2) the teeth involved in supporting the appliance move independently of the skeletal structures. Although it is probable that a combination of both factors occurs, it is apparent from previous studies using implants[8,12] that skeletal repositioning predominates until late in retention when the loads have decreased to physiologic levels more conducive to orthodontic tooth movement. Whether the skeletal repositioning that occurs is traumatic or is due to a physiologic reorganization of the contiguous maxillary sutures is a question for further study.The lack of dimensional changes incident to appliance removal following the retention period was interpreted as evidence that a stable relationship between the maxilla and the other bones of the facial skeleton had been created. The slight variable decrease in interbicuspid and intermolar dimension observed ten and thirty days after all retention had been discontinued may be attributed to the influences of the muscular drape, facets of occlusion and relapse of the portion of the expansion contributed by orthodontic tooth movement.

Based on the data reported in this and previous studies, the use of other than absolutcly rigid retention appears to be contraindicated until a condition of equilibrium has been established at the contiguous articulations of the maxilla.[10] In this frame of reference, absolutely rigid is defined as capable of withstanding loads up to twenty-five pounds while maintaining existing axial inclinations of the teeth. No conventional retention appliances (labial arch, lingual arch, or palatal plate) can comply with these requirements. If, for example, a removable acrylic palatal plate is used to hold the expansion, forces remaining within the facial skeleton could conceivably result in an undesired relapse of the basal structures rotating about a fulcrum at the lingual gingival margin while the crowns remain at a constant width. Therefore, only the rapid maxillary expansion appliance itself most nearly conforms to all the standards necessary for successful retention. The rapid relapse observed with premature appliance removal (patients *B* and *D*) emphasizes the need for a period of fixed retention. Furthermore, it appears that the length of time required for skeletal readjustment during retention is dependent upon the amount of residual load remaining at the termination of appliance activation, as the rate of load decay was essentially constant for all patients. Using a slower activation schedule, as in patient *D*, and thereby avoiding the accumulation of large residual loads, the retention phase of treatment may be significantly shortened while the total treatment time would remain essentially the same. Following this procedure may have its advantages in being less traumatic and thereby evoking a more physiologic response from the involved tissues.

The maximum relapse potential of the involved skeletal elements is evaluated according to the loads remaining on the expansion appliance at any particular moment. If these remaining loads prove to be active through specific measurable distances, which seems reasonable, judicious overexpansion to compensate for a predictable amount of relapse may also shorten the period of fixed retention and thereby allow conventional orthodontic therapy to be instituted at an earlier date. Subsequent investigation should provide answers to these questions as well as provide additional information regarding the biologic response of sutures in the facial skeleton to forces produced by rapid maxillary expansion and the effects of these forces on the involved teeth, periodontal membrane, and alveolar process.

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