A Clinical Assessment of Light and Heavy Forces in the Closure of Extraction Spaces

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Introduction

Relatively heavy, controlled forces have been in vogue in orthodontic treatment for a number of years. More recently there has been considerable interest in light forces, particularly during the early stages of treatment. This interest seems to have arisen, partially, as a result of reports of extremely short treatment time for consecutive cases by Begg. Documented evidence in support of light forces began to appear in the early thirties.

Schwarz'[13] conclusions, drawn from the reports of Sandsted and Oppenheim and from his own experimental data, favored the use of light forces. He stated, "Biologically the most favorable treatment is that which works with forces not greater than the pressure in the blood capillaries." He then proceeded to classify the degrees of biologic effect of tooth moving forces, noting that a strong force could strangle the peridontium, crush the soft tissues, and possibly cause the pulp to die. Forces of 15 to 20 grams per sq. cm. of tooth surface were optimum according to Schwarz.

Oppenheim[11] also advocated the use of light forces; however, he suggested that these should be of an intermittent nature. He presented evidence to show that forces applied at night only were effective and less damaging than continuous light or heavy forces.

Storey and Smith[14,17,18] used heavy and light springs, respectively, to apply initial forces of 400 to 600 grams and 175 to 300 grams. They found that in the case of the heavy springs only the anchor teeth moved until the force had decreased to the 200 to 300 gram range, then the cuspids began to move. Apparently the optimum force for moving cuspids was 150 to 200 grams. No measurable movement occurred in molars with forces under 300 grams or in cuspids under 150 grams. The maximum calculated movement of the cuspid was 0.1 mm per day.

Not to be neglected are Johnson,[6] Oliver[8] and their contemporaries who noted clinically the effectiveness of light forces, and aroused considerable interest in their respective approaches to treatment. Oliver has reported on the use of finger springs, the guide plane, and light elastics as the ideal sources of energy for movement of individual or groups of teeth. Oliver's guide plane and the activator of Andreasen make use of the masticatory muscles to produce intermittent but perhaps not always light forces. The clinical results shown by these groups unquestionably demonstrated that teeth could and would move efficiently in response to relatively light forces. One must realize, however, that in most light forces appliances there are many heavy, less obvious forces in action, i.e., the portion of the spring closest to its attachment to the primary archwire, the light twin wire nearest the end tube, and pressure areas resulting when light wires of loosely-fitting attachments allow teeth to tip.

In fact, in some of the preliminary phases of treatment the precision heavy wire advocates have conceded that a light wire can be useful and have more recently incorporated the advantages of light wires to prepare for the heavier, controlled forces. These men suggest

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that, even though light wires are to be used initially, all teeth should be banded for adequate control. Precision attachments for rectangular torque-producing wires are used to finish the treatment and place the roots in acceptable, stable positions.

In 1956 Begg[1] introduced a method of producing root torque force with light round wire and illustrated a number of cases treated very efficiently in this manner. Since this article appeared, there have been many short courses on Begg's treatment; those using this approach have apparently found this principle of treatment satisfactory in varying degrees.

Reitan[12] demonstrated the effect of mechanical forces on the tissues adjacent to the teeth being moved. Particular emphasis was placed on the production of hyalinized cell-free areas which retarded movement when excessive forces were applied. He noted that intermittent forces as light as 70 to 100 grams produced hyalinized areas on the pressure side, but of shorter duration than in continuous movement. Tipping forces were noted to have a greater tendency to cause hyalinization than those producing bodily movement.

Stoner[15] described a more refined and precise approach to the use of light forces and suggested that they should be applied continuously.

The purpose of this study was to evaluate clinically the effect of relatively light vs. relatively heavy forces in the closure of space at the site of extractions using segmented arches and closing loops. Several collateral areas of clinical interest were also considered. An attempt was made to evaluate: 1) rate of response to force; 2) pain; 3) degrees of expression of the energy in the closing loop in the interval between adjustments; 4) loss of anchorage; 5) degree of retraction of anteriors; 6) degree of tipping during movement; and 7) gross observation of the root structure and supporting tissues in the area of movement.

Method and Procedure

The clinical efficiency of light and heavy closing loops has not been fully documented, therefore this appeared to be a logical area for further investigation. Since practical application of research data is often difficult, this study was designed to be compatible with customary methods of handling patients in a private orthodontic office. The procedure was designed to measure the results of the two degrees of force used to close extraction space. In our office the intent is to schedule appointments at three week intervals; however, a four week interval is more common than three. It was noted in every instance that the closing loops which provided the force had completely expended their energy by the time one month had passed, consequently the loop was passive during part of the period. Since a number of patients had already been started on this four week program, it appeared that a second group should be included and measurements made at approximately two week intervals. Therefore, to simplify presentation of the material the study was originally divided into Phase I and Phase II.

All four first bicuspid extraction patients were utilized as they appeared for treatment. Generally, the mandibular spaces were entirely closed with closing loops while the maxillary arch was relatively passive with an .018 wire and bands on the first molars, second bicuspids and cuspids. In the space closure areas, except where noted, the first molars, second bicuspids and cuspids were banded with .022 x .028 edgewise brackets and tubes. A single helix of .015 stainless steel wire was incorporated into a single closing loop on either the left or right side at random (Fig. 1). A single closing loop as described by Stoner was incorporated

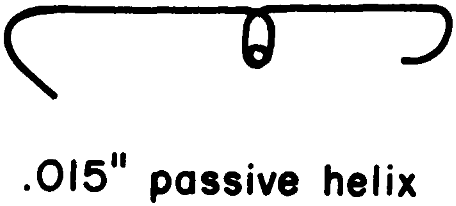


Fig. 1

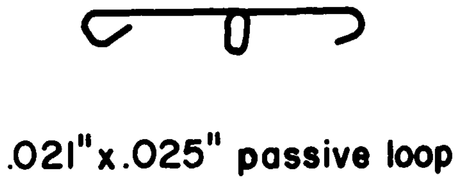


Fig. 2

into an .021 x .025 stainless steel wire and placed in the same arch but on the opposing side (Fig. 2). Both loops were adjusted by cinching the wire posterior to the molar tube until the legs of the loops were completely closed. This amounted to approximately 1.5 mm. The pull force resulting from activation of the light helix was 150 to 200 grams. The force resulting from activation of the .021 x .025 Stoner closing loop was 1200 to 1500 grams. As soon as the extraction spaces were closed in the mandibular arch, the procedure was repeated in the maxillary arch. At this time cervical traction force was applied to the upper molars where necessary. Two cases were treated with closing loops in the spaces resulting from the extraction of mandibular first molars. One case involved extraction of mandibular and maxillary second bicuspids.

1. Measurements were made with a needle point Boley gauge at the point of greatest convexity on the proximal band surfaces.
2. Mandibular anchorage slippage was determined by relating the mandibular and maxillary molars, after space closure, to those on the casts before treatment. Where cervical traction force was utilized in the maxillary arch, no attempt was made to measure loss of anchorage.
3. Cephalometric x-rays were obtained before treatment and after retraction of the cuspids. These were to be evaluated for changes in cuspid and molar positions.
4. Periapical x-rays were obtained before treatment and at the extraction sites after space closure. These were examined in order to determine the effectiveness of the appliances in paralleling the roots of the bicuspids and cuspids and for assessment of root and bone changes in the area.
5. Relative pain was determined clinically by asking the patient to report on the discomfort of one side vs. the other.

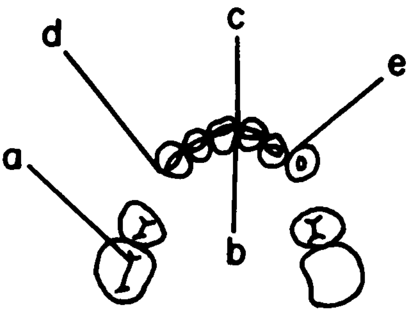
Phase II

When twenty subjects had been treated as described, it was decided that as many more as time would permit would be treated in a like manner but observed at ten day intervals. Once again the dictates of the practice determined that the time interval would average two weeks instead of ten days as planned. Measurements and assessments of pain were made in the same manner as described in phase I.

Phase III

During the summer and fall of 1969 a group of patients were treated as in phase II of the 1962 study. Control of anchorage was assessed in this group by measuring the distance from the most mesial part of the occlusal groove of the first molar to the lingual alveolar bone, midway between the mandibular central incisors (Fig. 3). Relative movement of left and right canines was determined by measuring the distance from the most mesial surface of the canine to the interproximal, labial to the central incisors (Fig. 3).

Rates of space closure were measured as in the 1962 study.



Points of measurement
Fig. 3

Results—1962 Study

The first data were derived from measurements taken after the closing loops had been activated and allowed to dissipate their force for approximately four weeks. There were some variations due to mechanical failures or other factors not considered related to the proper evaluation of the study. In those instances the measurements were not included.

The initial response of the forces will be presented as a matter of academic interest since the compression of the periodontal membrane, effect of undermining resorption, and the time required for stimulation of osteoclastic activity, etc. has been discussed in other papers. The mean initial amounts of space closure at the site of a mandibular first bicuspid extraction under treatment with a light .015 helix as compared to a .021 x .025 closing loop are shown in Table I. The responses to similar forces over four week intervals on subsequent adjustment are noted in Table II. When the interval between appointments was shortened to an average of two weeks, the following data were accumulated; all are initial response measurements in the mandibular arch (Table III). The amount of space decrease was similar in any period of adjustment, i.e., the initial response to pressure was comparable to the second, third or fourth response.

In several cases measurements were available on the maxillary areas. Since

Phase I Initial Response, Four Weeks

Light force, 14 areas, 14 subjects	Heavy force, 16 areas, 16 subjects
Mean response 1.0 mm	Mean 1.8 mm
Range 0.7 to 3.0 mm	Range 0.8 mm to 3.0 mm
S. Dev. = 0.6 mm	S. Dev. = 0.7 mm

TABLE I

Phase I - To Space Closure (4 week intervals)

Light force, 12 areas, 12 subjects	Heavy force, 11 areas, 11 subjects
Mean 1.3 mm	Mean 1.4 mm
Range 0.8 to 2.1 mm	Range 0.9 to 2.5 mm
S. Dev. = .4 mm	S. Dev. = .5 mm

TABLE II

Phase II

Initial 2 week closure

Light force, 9 areas, 9 subjects	Heavy force, 9 areas, 9 subjects
Mean 1.0 mm	Mean 1.0 mm
Range 0.4 mm to 1.8 mm	Range 0.5 mm to 2.0 mm
S. Dev. = 0.4 mm	S. Dev. = 0.5 mm

TABLE III

the number of cases is small these measurements will not be included; however, they appear to be of the same character as those obtained under similar circumstances in the mandibular arch.

First permanent molars were extracted for two patients and subjected to the same treatment as the previous cases. The second permanent molar was pitted against the first and second bicuspids. The response was in the order of 1 to 2 mm over four week intervals.

In another subject, second bicuspids were extracted and the first permanent molars were pitted against the first bicuspids and permanent cuspids in the maxillary arch. The space closure under conditions similar to the previous cases varied for 1 to 2 mm over four week periods.

An attempt was made to evaluate anchorage loss through the use of oral and cephalometric landmarks. The complicating factors were so great that the measurements will not be included. There did appear to be a greater loss of molar anchorage on the side of heavy force in several subjects; however, this was not consistent enough to merit consideration.

Gross tipping of teeth was noticed particularly in the mandibular arch. This may be partially due to overactivation of the loops. Destruction of the lamina dura was always noted on the side of pressure. In several instances the teeth were moved so rapidly that the original lamina dura appeared to be intact and separated from the tooth by immature bone on the side of traction (Fig. 4). The apices of the roots appeared to have moved in the opposite direction to the crowns of the teeth in most instances. Supporting structures were severely disturbed in every instance.

Both the light and heavy closing loops were very inadequate with respect to the bodily movement of teeth. Tipping of teeth was in evidence clinically and in the periapical x-rays, more particularly in the mandibular arch. Insertion of leveling arches corrected this situation quite rapidly.

All the subjects experienced some degree of discomfort. Initially the insertion of the heavy wire was more painful; however, this discomfort disappeared after one to three days. Several subjects stated that they experienced more discomfort in the area of light force.

Discussion

The number of subjects involved in the study is too small to permit definite conclusions to be drawn. However several trends were noted.

The difficulties encountered in attempting to measure the distance between teeth which are in the process of tipping and rotating are many.

Reitan's[12] method of placing small circular restorations in the occlusal surfaces of the teeth adjacent to the ex-

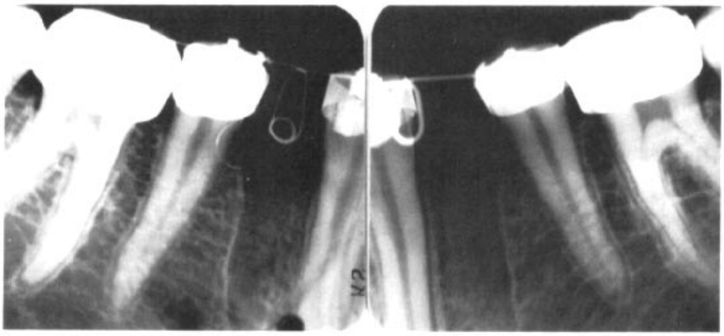


Fig. 4 Alveolar status after two weeksactive treatment with .015 helix left and .021 x .025 closing loop right.

traction site was considered, but proved to be impractical in a private practice. Also this method would not account for rotations or tipping any more than that of measuring the distance between the proximal band surfaces.

The time interval between measurements varied as much as several days. Appliances were distorted by masticatory forces and tissue response varied between individuals, yet the standard deviation values are quite small.

Interestingly, the means are nearly identical in both the light and heavy force measurements. This holds true in initial as well as secondary and tertiary measurements.

It is also interesting to note that the space closed approximately as rapidly in the first two weeks when forces were heaviest, (as much as 1200 to 1500 grams for the single heavy loop) and tissue hyalinization supposedly would delay movement for several days, as it did in the subsequent intervals. The compression of the periodontal membrane may have accounted for a portion of the movement at the initial adjustment.

Data obtained from measurements of the individual areas of closure and from the several means indicate that a reduction of the space by 0.5 mm per week can be anticipated with any force from 150 to 1500 grams. The optimum length of time between adjustments apparently depends on the length of time the closing mechanism will remain active. The average time required for closure of bicuspid extraction space should be twelve to sixteen weeks, unless the anchor teeth are stabilized.

Movement of as much as one millimeter in the heavy force areas in six days does not agree with Reitan's findings. In fact, results of the various parts of this study related to heavy forces do not coincide with the reports of many other investigators. Therefore, one must conclude that there are inaccuracies in technique, or that hyalinization of the potential osteoid areas and the production of cell-free areas does not deter the tooth from moving for a significant length of time. Histologically, hyalinization is well documented; however, the relative speed of movement of a tooth through or into an area of undermining resorption vs. that of one moving into a well-organized area of osteoid cellular tissue is not well established. The implication is not that heavy forces are more desirable than light ones, but that heavy forces will move teeth as rapidly as light forces.

An examination of the radiographs would force one to conclude that there is a severe disturbance of the periodontal tissues when either light or heavy forces are applied. It would also be necessary to concede that there is evidence of loss of anchorage in the use of either type of force.

The response to questions regarding pain indicate that the only disadvantage of heavy forces in this respect was in the initial seating of the appliance and for 24 to 48 hours following this. However, the light forces also cause considerable discomfort to most subjects for 24 to 48 hours after adjustment. Application of a relatively rigid rectangular archwire after an initial period of leveling with light round wires would eliminate most of the discomfort at the time of application and retain the control inherent in the rigid rectangular wire.

Tipping of all mandibular teeth adjacent to the extraction area can be attributed to an inadequate degree of rigidity in the .015 helix. The tipping in the heavy force areas was partly due to distortion of the loop by over-activation. Effective application of heavy rectangular closing loops requires that they be adjusted below their elastic limit. This does not explain the bodily movement generally observed in the maxillary areas. Apparently there is some relationship of the difficulty in moving the apex of the mandibular tooth to the severity of tipping produced.

Anchorage loss was not accurately determined clinically. Radiographically the maxillary posterior teeth showed the greatest loss of anchorage and insult to the periapical tissues. Apparently the only stable anchorage is extraoral.

Unquestionably extraction of four first bicuspids and subsequent mechanical space closure is always a severe insult to the supporting tissues. Whether this insult leaves a permanent scar or not is a subject for considerable research and study.

One cannot help but notice the destruction of the lamina dura on the side of pressure. Nor can one examine the x-rays of patients who have undergone bicuspid extractions and fail to notice the blunting of the interproximal alveolar crest in every case and lack of contact between teeth in many areas.

1969 Study

The preceding discussion applied to a study finished in 1962. Since the results were inconclusive and seemingly incomprehensible, an attempt was made again in 1969 to determine the most effective force to be used for closure of first bicuspid extraction sites.

Subsequently Hixon[16] et al. in 1969 reported on optimal forces. His comprehensive study concluded that: 1) When applied to canine retraction for a clinically useful period of time, there are no data to support the theory of optimal force; 2) The rapid tooth movement of the "light" forces appears to be the result of tipping which produces a high load at the alveolar crest; 3) The maintenance of molars in an upright position is relatively effective in resisting the canine retraction by distributing the force over a larger root area.

Hixon and his students' findings agree with those of our 1962 study and are reinforced by the recent 1969 study.

Patients again reported different degrees of pain and in several cases no pain of any kind with either forces. Heavy force adjustments were more painful because of the brute force required in adjustment; however, the duration and intensity of pain could not be correlated with the amount of force.

Rotations did not present as great a problem as did tipping of teeth.

The secret of greater rapidity of space closure would appear to be one of control and continuous application of force. The tooth can possibly be moved as rapidly bodily as when tipped and this will result in less time spent in uprighting. However, many methods of treatment incorporate an uprighting

Response of Anchorage Units VS. Canines

Patient	Light Force	Molar Drift	Cuspid Retraction	Heavy Force	Molar Drift	Cuspid Retraction
B	LR. 015	1.5	2.5	LL. 022	2.0	2.5
C	LR. 018	3.0	2.0	LL. 020	2.5	1.5
D	LL. 015			LR. 020		
M	LR. 015	1.5	2.5	LL. 018	1.0	4.0
E	LR. 015	4.5	2.2	LL. 020	5.0	2.5
P	LL. 016	2.5	3.0	LR. 020	3.0	2.0
F	LL. 015	2.0	2.0	LR. 020	3.0	3.0
G	UR. 015	3.2	2.1	UL. 022	3.0	2.8
N	LL. 016	2.8	3.3	LR. 020	3.0	4.0
H	LR. 015	2.0	2.5	LL. 021 x .025	3.0	1.5
O	LR. 015	3.5	4.0	LL. 021 x .025	1.2	2.4
J	LR. 015	3.0	3.5	LL. 021 x .025	2.0	2.0
Totals		29.5	29.6		28.7	28.2
Mean movement until space closure on one side		2.7 mm	2.7 mm		2.6 mm	2.6 mm

TABLE IV

technique with incisor alignment and bite opening. This may result in less strain on anchorage than bodily movement of the cuspid.

Movement of anchorage units as related to canine retraction is difficult to evaluate since tipping of teeth and movement of landmarks is a part of the over-all tissue change. A general observation would be that all the forces used were adequate to initiate cellular response around the molars and in many cases the anchor units responded to the space closing device as rapidly as did the canine (Table IV).

Space Closure

Measurement of space closure was made without reference to anchorage loss and represents the total response of tissues in the area to certain forces applied to the teeth. The .015 device was a closing loop with a helix, supplying a force of approximately 200 grams. The .018, .020 and .021 x .025 loops were simple reverse loops in a sectional arch. All the forces provided space closure increments of .4 to .5 mm per week measured over six and ten week intervals. (Table V).

The number of heavy force measurements is small but the average of .4 mm per week as compared to the .5 mm per week for all other forces apparently does not warrant the use of extremely heavy forces for space closure alone.

Summary

1. The 1962 and 1969 studies basically agree with Hixon.
2. Forces produced by closing loops can be comparatively powerful. 150 to 200 grams of force is adequate to move most teeth, therefore it seems unnecessary to use a force of 1200 grams when 150 grams is as effective. Yet the control afforded by the heavy wire makes its use mandatory for many purposes. The use of auxiliary springs in conjunction with the precision edgewise appliances should provide a source of gentle yet precise movement.
3. .5 mm space closure per week can be anticipated when forces of 150 to 1200 grams are used.

Movement in Six Weeks

Wire size	.015	.018		.020		.021 x .025	
Force	150 gms	720 gms		960 gms		1500 gms	
Patient							
A	3.8	C	3.0	A	3.6	H	3.1
B	3.8	M	2.6	D	2.6	I	1.7
C	2.5			E	3.0	O	2.8
D	2.7			F	2.2	J	2.7
E	2.7			N	3.0	K	1.5
F	3.5					L	2.3
G	3.4						
H	2.4						
I	1.1						
J	2.6						
K	1.7						
L	1.7						
Totals	31.9 n=12	5.6 n=2		14.4 n=5		14.1 n=6	
Mean					2.9		2.4
Average movement per week	0.5 mm	0.5 mm		0.5 mm		0.4 mm	

TABLE V

4. Reciprocal forces will affect all teeth involved. The greater the amount of root surface in the anchor area, the less likely it will be to succumb to forces light enough to move one cuspid. Since anchorage posterior to the cuspid is limited, cervical traction should be utilized to prevent undesirable posterior anchorage slippage.
5. Movement of teeth causes discomfort to the patient under most circumstances; this is not an excuse for the use of unnecessarily traumatic forces.
6. Minimum forces were not tested but those supplied by an .015 round wire with a reversed helix loop were more than adequate to move all the canines tested.
7. Complicating factors such as tipping make an accurate assessment of the efficiency of movement very difficult.
8. Further investigation of precision appliances with light force auxiliaries should provide valuable clinical information.

Conclusion

1. A speculation that continuous forces of less than 200 grams could move canines without moving posterior anchorage is in order. Inclusion of first and second molars and second bicuspids may be necessary to overcome the canine resistance. The long rooted canine may have as much resistance to movement as a molar and bicuspid. A long acting continuous source of energy is most important in efficient space closure. Cuspid to cuspid compressed coil springs are a very efficient, long acting source of energy. Teeth moved along an archwire of adequate size do not tip excessively, particularly

when brackets are inclined for controlled movement.

2. Pain is apparently related more closely to patient tolerance than to the forces used.

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