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Space Closure Efficiency with Modified Ceramic Brackets : A Comparative Study

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ABSTRACT

SPACE CLOSURE EFFICIENCY WITH MODIFIED CERAMIC BRACKETS

A COMPARATIVE STUDY

by

Kirk A. Specht

The purpose of this study was to determine if the rate of extraction site closure was determined by the type of ceramic bracket used. A new ceramic bracket with a metal archwire slot was compared with a conventional ceramic bracket. Twenty patients were randomly assigned the metal slot ceramic bracket and conventional ceramic to one half of their maxillary arch respectively. The distribution was even left and right.

Retraction was started and completed on an 0.016" stainless steel round continuous archwire. One hundred gram sentalloy springs provided a uniform retraction force and were reactivated every four weeks to maintain a constant force measured at 100 grams.

Retraction continued until contact occurred between the retracted tooth and the most posterior tooth adjacent to the space. At this point retraction was considered complete and final records were taken.

The initial lateral cephalagram was compared to the progress cephalagram. Measurements from PTV to each first molar and to each anterior tooth being retracted were used in a subgroup of eight patients with essentially identical treatment methods. These were used to determine if binding

or resistance to space closure occurred more frequently with one bracket type.

The results of space closure were analyzed using a regression analysis to evaluate millimeters of movement per month for each bracket and tooth measurement for each patient. Correlation was high in all cases and rate of retraction of the 17 patients that completed the study showed no significant difference from one bracket type to the other ($p=0.61$). When the values to PTV were compared using a Paired T Test, no indication of increased binding or friction could be shown from one bracket type to the other ($p=0.25$).

While there may be other advantages to the metal slot insert, such as improved resistance to fracture or ease of wire placement, there appears to be no specific advantage regarding rate of retraction or reduction of friction according to the results obtained from this study.

LOMA LINDA UNIVERSITY

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Each person whose signature appears below certifies that this thesis in their opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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INTRODUCTION

Ceramic brackets used in orthodontic tooth movement today fall into two major groups. Polycrystalline alumina and single crystal sapphire. The majority of ceramic brackets in use at this time are polycrystalline alumina with either molded or milled bracket anatomy. Polycrystalline brackets, also known as ceramic brackets, are manufactured with strict tolerances for uniformity. The surface of the bracket after fabrication however, is microscopically rough[1,2] which is thought to cause increased frictional resistance between the wire and the bracket[1-3]. This resistance, presumably, inhibits efficient tooth movement, and causes abrasions to the archwire which limits the wires usefulness.[4] This study evaluates a prototype ceramic bracket with an integrated metal sleeve within the arch wire slot[A]. Since the liner is within the slot, the appliance retains a high level of esthetics while seemingly changing the characteristics of the bracket to that of a conventional metal bracket. While the concept of a metal slot in an esthetic bracket has been used in modified plastic brackets[B], until now, no such bracket has been introduced in ceramic. If sliding mechanics are adversely affected with current ceramic bracket designs, then

A. 3M/Unitek, 2724 South Peck Road, Monrovia, CA 91017-7118, Transcend and prototype Transcend with metal slot.

B. Spirit Brackets from Ormco, A Subsidiary of Sybron Dental Specialties, Inc., 1332 South Lone Hill Avenue, Glendora, CA 91740.

improving the archwire to slot interface would be of benefit to orthodontic treatment.

The purpose of this investigation is to determine whether sliding mechanics efficiency is improved during space closure in extraction cases with the use of the metal inserted ceramic bracket.

Many studies on "friction" have been done to help us determine more effective mechanics to move the teeth to their desired position.[1-4,5-25] Surface topography and frictional characteristics of ceramic brackets have been evaluated and indicate that rougher surfaces generate more resistance to tooth movement.[1-4,10] The type of wire used as well as the size and shape of wire also affect the potential rate of tooth movement.[17,9, 11,15,19,21,22,24,25] Interestingly, some studies have shown that frictional resistance to tooth movement decreases when larger wires were used,[25] especially in the area of the buccal sections.[19] An increase in archwire angulation or deflection causes greater friction,[1,5-11] binding, or at least the effect of slower tooth movement. The combination of various wire types and sizes with metal and ceramic brackets yields varying degrees of friction.[1,5-11] In general, ceramic brackets have the greatest friction when used with TMA wires.[4] Metal brackets with stainless steel wires seem to offer the least resistance.[2,7, 9,11,17,20,24]

In an unpublished laboratory study done by Bechtol and Nguyen, four brackets were used to study friction. Two

ceramic brackets, a metal slot inserted bracket identical to the one used in this study and a metal bracket were compared. Their findings indicate the metal slot exhibited the least amount of friction followed in order by, the prototype metal slot ceramic, and the last being the traditional ceramic brackets.[20]

Other factors related to friction include method of ligation and lubrication.[1,13,18,19 22,23,25] Wire ligation reduces the overall binding of the wire as compared with elastomer ligation techniques.[18,19,25] Kusy et al have been comparing dry, synthetic saliva, and human saliva effects on friction for some time. Their findings with a stainless steel wire show an increase in resistance to tooth movement from friction when human saliva is present due to an adhesive affect between the wire and the bracket.[1]

All of these studies assist in our understanding of the relationship of friction and binding in an edgewise system. However most of these are bench studies, and very little in vivo clinical research has been done to add to this knowledge. While this research does not attempt to evaluate all of the factors related to tooth movement and bracket/wire binding, it does compare the rate of closure of extraction sites within individual patients. This data might help develop conclusions regarding the benefit of metal slot liners in ceramic brackets for frictional control. The null hypothesis of this research is that no difference exists

between the two brackets studied relative to the properties that affect resistance to tooth movement.

MATERIALS AND METHODS

This study was performed coincident with routine orthodontic treatment done at Loma Linda University School of Dentistry's Orthodontic Department. Only the upper arch was evaluated. Each quadrant was bonded from central incisor back to the second premolar using one of the two brackets randomly selected for that side of the arch.

Two types of 0.018" X 0.025" brackets were used. A traditional ceramic bracket with a milled ceramic slot and a newly developed ceramic bracket with a metal slot. The study consisted of twenty orthodontic patients, 7 boys and 13 girls, ages 11 to 15, undergoing premolar extraction therapy. Standard clinical records for the T-1 series for each patient were taken. The lateral cephalametric x-ray was later used to evaluate anchorage loss. Models and photographs also recorded each patients condition prior to any treatment. At the time of bracket placement additional models and photos were taken. In some cases the patients extractions were completed at this point, in others, the teeth designated to be removed were just not bracketed. Patients were seen on a four week interval. At each appointment four photographs and four measurements were taken for the patients and the

retraction springs were activated to the specified 100 grams of force for each side[C].

On all patients bands were placed on the first molars, and second molars when indicated. The remaining maxillary teeth were bonded with an 0.018" X 0.025" Roth prescription consisting of one half metal slot ceramic and the other half standard ceramic from the same manufacturer. All ceramic brackets were bonded using the same light cured bonding material[D]. The arches were leveled until an 0.016" stainless steel archwire could be placed. At the placement of the 0.016" stainless steel archwire, retraction was initiated using a 100 gram sentalloy spring. The springs were selected over elastomeric chains because the force delivered by elastomeric chains degrades rapidly[27,28] and nickel-titanium springs deliver a more constant range of force over a longer period of time. The spring was attached to the molar elastic hook and the body of the bracket of the tooth being retracted. All retraction was done on continuous arch wires using the same retraction method and wire.

On all patients a gauge, measuring grams of force, was used to measure the 100 grams to be delivered during retraction. A space was determined to be closed when the two teeth were in physical contact. Anchorage control was not an

C. GAC International, Inc., 185 Oval Drive, Central Islip, NY 11722-1402, 100 gram open coil Sentalloy spring.

D. 3M/Unitek, 2724 South Peck Road, Monrovia, CA 91017-7118, Transbond, light cured adhesive.

aspect of this study, however a group of eight patients had essentially the same method of treatment requiring no planned anchorage and served as a subgroup in this study. The remaining patients had various forms of anchorage requirements specific to their treatment plans.

The routine records taken at each visit consisted of a series of photographs, including a facial, a right and left intraoral buccal section, and a maxillary occlusal view. Each of the buccal section views had a clear plastic millimeter rule placed above the teeth being analyzed to help verify the relationships for future reference. The occlusal view was taken to help analyze any potential tipping or rotation that may occur during retraction. The spaces were then physically measured intraorally using a divider and a Boley gauge (Figure 1) and these measurements were recorded to the nearest tenth of a millimeter.

Two measurements were taken on each side at each visit. The first measurement was the mesial of the molar bracket at the slot to the distal of the bracket on the tooth being retracted. The second was the shortest distance along the convex surfaces between the two teeth, measured from tooth surface to band surface on the molar in second bicuspid extractions and from the tooth surface to tooth surface in first bicuspid extractions. When space closure was complete on both sides, the series of photographs and measurements along with new models,

maxillary and mandibular, and a progress cephalagram was taken.

The data collected was then separated into four groups, based on the right and left measurements. The right and left side bracket to bracket(B-B) group, and the right and left tooth to tooth (T-T) group. The double measurement taken on each side was for the purpose of giving a dual comparison of data to further reduce potential for error in the results. A regression analysis was used to look at the data comparing right and left retraction rates under the same conditions. These rates where then compared using the Wilcoxon Signed Ranks Test to determine whether or not the rate of retraction for one bracket type was significantly faster than the other.

In the group of eight patients having identical treatment, measurements were taken to include the cephalametric measurement of PTV to distal of the right first molar, PTV to distal of the right cuspid, PTV to the distal of the left first molar and PTV to the distal of the left cuspid. These linear values were used to evaluate whether the areas of closure occurred more due to the molar moving mesial or the cuspid moving distal. The distances were compared before and after and Paired T Tests were run to relate the findings of the metal ceramic side to the conventional ceramic side.

Friction or binding of the archwire could then be determined in two ways. One, in the group as a whole between

right and left sides, and two, with the subgroup of eight to determine if increased binding or friction related to loss of molar anchorage occurred thus affecting which direction the space closed.

RESULTS

Table 1 shows the anchorage relationships of the eight patients with identical treatment plans for anchorage. Paired T Tests were run to evaluate the amount the anterior tooth slipped back during space closure as well as the amount the molar slipped forward. The Paired T Tests were done comparing anterior metal side to ceramic side only, the posterior molar side to opposite molar side only and the total space closure for each side comparing anterior and posterior tooth movement. The results indicated no significant degree of binding or anchorage variability between the metal slot ceramic side and the conventional ceramic side. ($p=0.25$)

Table 2 shows the bracket to bracket correlation coefficient and regression coefficient (the rate of change in mm/month) for each patient comparing the metal slot ceramic brackets with the conventional ceramic bracket. The number of visits (n) that it took for each patients space to close is also included. Table 3 shows the same data for the tooth to tooth measurements. The average rate of space closure in millimeters per month was

1.40 mm for the metal slot side and 1.44 mm for the conventional ceramic side.

A Wilcoxon Signed Ranks Test was performed comparing the regression coefficient values for the metal and ceramic slot brackets. No difference was found between the brackets studied. ($p=0.60$)

DISCUSSION

This study looked at the rate of closure in upper premolar extraction cases using two ceramic bracket systems randomly placed, right and left, for each patient. The use of .016 continuous arch stainless steel wire was effective as a retraction wire due to its minimal binding resistance and adequate size in an 0.018" X 0.025" slot. Minimal tipping and very little undesirable rotation occurred as is illustrated in Figure 2, showing an occlusal view of case number 13.

A clinical study carries with it some challenges that should be reviewed. Bond failure, while not a common problem in porcelain brackets, did occur in 4 instances. These bond failures occurred during the initial leveling process prior to the start of retraction, and should not have influenced our results. Each bracket that failed was replaced with a new bracket of the identical type originally designated randomly for that tooth. There were also two tie wing

fractures from the conventional ceramic group that occurred during the course of the study.

Some changes in protocol were necessary after six months. The recording of tooth to tooth measurements in addition to the original bracket to bracket measurements. Also occlusal photographs were added to help determine any undesirable changes in rotation or tipping along the long axis of the tooth. These changes while improving the study left a smaller number of visits to compare rate of closure, specifically in the tooth to tooth regression analysis as can be seen in Table 2.

Another variable which was difficult to control in a clinical study was the regularity of patient visits. Missed appointments break up the regular four week time interval originally planned for patients records. This required entering blank spaces in the data sheet. Figure 3 and 4 show a graphical view of patient #17 who missed their second appointment after initiating retraction. The large jump from activation #1 to activation #2 is a result of twice the normal four week activation interval. It does however demonstrate and support the long period of activation present in the sentalloy springs. While this is not ideal, it does continue to yield valid results as this project compares right to left within a given patient and both sides receive the same lack of reactivation when an appointment is missed.

The issue of which teeth were extracted also potentially could have some bearing on the results. Some patients had

upper first premolars removed while others had the seconds extracted due to differing anchorage needs. In case #3, the upper left second premolar and upper right first premolar were extracted. This was necessary to treat an asymmetry present in this patient's dentition. After leveling in this case very little movement was required to advance the second premolar into contact with the canine so that retraction on both sides could begin simultaneously and from nearly the same relationship. When comparing the data in Table 2 and Table 3 there does not seem to be any indication that this resulted in erroneous conclusions.

In our patient sample, the majority exhibited six or more millimeters of maxillary crowding. Frequently by the time leveling had occurred only two to three millimeters of space remained to be closed. In cases 1, 4, 7 and 15, at least one and sometimes both sides were closed in just two visits. This gives an invalid correlation coefficient with only two points. The fortunate side is that by measuring both bracket to bracket and tooth to tooth distances only #15 should really be considered in question.

Still other issues like adequate sample size created challenges. With between 10-15% extractions being treatment planned at Loma Linda University it was difficult to sign up enough patients for a valid research study. By doubling the anticipated project time enough participants became involved to yield statistically significant data. Some extraction patients just wanted metal brackets. Some patients declined

to be part of this study due to concerns of potential enamel fractures with the use of porcelain brackets. Finally, four patients had incomplete space closure for various reasons and could not be included.

The rate of space closure after extractions, when using two types of brackets, was what was measured in this study. However the point of interest in orthodontics is what really affects this closure rate. Friction has been discussed as a cause of delayed retraction. Another cause that is a significant factor is the binding effect as the tooth tips and jiggles back along the archwire. Contact of the roots with the cortical plate certainly impedes retraction rate. From the statistical results of this research it appears that the type of arch wire bracket interface may be a lesser concern when it comes to space closure than these other factors.

The location and degree of anchorage loss during retraction was also evaluated. The initial lateral cephalagrams were compared to the progress cephalagrams taken at the end of retraction. A measurement from the pterygoid vertical to the upper first molar right and left and the upper canine (retracted tooth) right and left was taken. These were compared and tabulated (Table 1) to determine the affect various anchorage forms had on preventing forward movement of the molars. Of the 16 patients completing the study, 15 had all the necessary radiographs to complete the

anchorage analysis. Eight of these patients had minimum anchorage, five had moderate anchorage and two had maximum anchorage. Table 1 details the findings of those with the same treatment plans for anchorage, the minimum anchorage group.

When looking at the group as a whole there was no significant difference between conventional and metal slot rates of retraction. When evaluating the eight identical, the same results were seen. No difference in anchorage or anchorage loss could be seen in the anterior segment, the posterior segment or anterior and posterior together comparing side to side.

It is recognized that during the variable period of time from the T-1 lateral cephalagrams, to the beginning of retraction after leveling, some growth occurred affecting the validity of this measurement. There is a degree of error in measuring PTV to the distal of specific teeth and it was accepted the small amount of growth that did occur for each patient would not significantly alter the results. What ever error was introduced was produced on both sides equally and the evaluation of anchorage or binding within the bracket types should be valid.

SUMMARY AND CONCLUSIONS

Space closure was evaluated and compared in this clinical study. From our findings the following conclusions

were drawn regarding resistance to tooth movement.

- The wire to bracket slot interface as designed in this study, do not seem to significantly alter the rate of retraction in maxillary extraction cases.
- Potentially the greatest factor affecting the rate of space closure may be binding during the repeated tipping action that occurs during retraction.
- From the comparison of anchorage loss that occurred among eight patients with identical anchorage, it was determined that no difference in anchorage control, friction or binding seemed to exist between the two bracket types.

Potential for further study can certainly be done with the work that was started here. This study focused on the rate of space closure in millimeters per month for two specific bracket types. Also anchorage was evaluated to determine its effects within the two bracket types when identical treatment plans for anchorage were used. A larger sample size including other anchorage needs but evaluating the same variables would further contribute to our understanding of these topics.

APPENDIX

RECORD OF PATIENTS RETRACTION

NR = no records

Patient Number	Date	mm Bracket to Bracket		mm Tooth to Tooth	
		Right	Left	Right	Left
1	4-12-94	8.0	10.0	NR	NR
	5-12-94	Failed			
	5-31-94	8.7	7.3	NR	NR
	7-5-94	6.4	6.2	0.7	0.8
	8-4-94	NR	NR	closed	closed
2	5-16-94	8.3	10.0	NR	NR
	6-8-94	Failed			
	6-29-94	7.4	7.1	1.6	3.1
	7-27-94	6.1	6.0	0.7	1.3
	8-11-94	NR	NR	closed	0.3
	moved	NR	NR	closed	closed
3	4-13-94	11.2	10.7	NR	NR
	5-12-94	10.2	9.9	NR	NR
	June	Failed			
	7-1-94	9.0	8.5	3.8	2.4
	8-1-94	7.8	6.2	2.9	0.4
	9-2-94	6.1	6.0	1.4	closed
	9-30-94	NR	NR	0.5	closed
	11-3-94	4.2	5.7	closed	closed

RECORD OF PATIENTS RETRACTION

NR = no records

Patient Number	Date	mm Bracket to Bracket		mm Tooth to Tooth	
		Right	Left	Right	Left
4	4-25-94	14.6	10.5	NR	NR
	5-23-94	11.8	8.8	NR	NR
	June	Failed			
	July	Failed			
	8-22-94	Failed			
	9-7-94	8.5	6.3	1.8	1.2
	10-10-94	6.5	5.1	0.5	closed
	11-7-94	NR	NR	closed	closed
5	4-3-95	11.0	7.7	3.8	1.3
	Inadequate time to include as part of the research.				
6	5-3-94	14.4	12.9	NR	NR
	5-31-94	12.1	11.1	NR	NR
	June	Failed			
	July	Failed			
	8-23-94	NR	NR	2.5	2.4
	10-4-94	15.7	14.8	0.9	0.8
	11-8-94	13.8	13.1	closed	closed

RECORD OF PATIENTS RETRACTION

NR = no records

Patient Number	Date	mm Bracket to Bracket		mm Tooth to Tooth	
		Right	Left	Right	Left
7	5-11-94	12.2	10.8	NR	NR
	6-8-94	9.1	8.5	NR	NR
	7-26-94	6.9	6.4	1.3	1.0
	8-23-94	5.1	4.3	closed	0.2
	9-27-94	4.5	3.7	closed	closed
8	8-3-94	16.5	15.2	3.2	3.1
	8-30-94	15.1	13.0	2.0	0.3
	10-4-94	13.1	11.5	0.4	closed
	11-8-94	12.1	11.4	closed	closed
9	6-10-94	NR	NR	NR	NR
	7-15-94	NR	NR	3.1	3.9
	8-19-94	NR	NR	3.2	2.4
	10-4-94	13.9	13.9	1.4	1.5
	11-11-94	13.5	12.8	closed	.07
	12-8-94	13.5	12.2	closed	closed
10	10-5-94	19.0	17.8	4.2	3.1
	11-29-94	16.7	15.3	1.6	1.3
	1-3-95	NR	NR	0.6	closed
	1-31-94	13.4	12.8	closed	closed

RECORD OF PATIENTS RETRACTION

NR = no records

Patient Number	Date	mm Bracket to Bracket		mm Tooth to Tooth	
		Right	Left	Right	Left
11	11-9-94	14.0	10.5	6.8	4.5
	12-7-94	13.2	8.9	5.5	3.5
	1-4-95	11.6	8.7	5.1	2.5
	2-1-95	9.9	7.7	3.7	2.0
	3-1-95	8.5	6.0	2.4	1.2
	3-29-95	6.7	4.9	1.4	closed
	4-26-95	6.2	4.7	0.5	closed
	5-18-95	5.7	4.9	closed	closed
12	1-13-95	9.9	9.7	3.0	2.6
	2-11-95	8.9	9.0	2.1	1.9
	3-10-95	7.7	6.5	1.3	0.5
	4-7-95	6.1	6.1	0.5	closed
	4-21-95	5.7	6.6	closed	closed
13	12-2-94	10.5	10.7	5.0	4.3
	1-4-95	8.8	8.8	3.4	2.8
	2-1-95	8.1	6.8	2.3	1.7
	3-3-95	5.5	3.9	0.8	closed
	4-7-95	4.8	4.5	closed	closed

RECORD OF PATIENTS RETRACTION

NR = no records

Patient Number	Date	mm Bracket to Bracket		mm Tooth to Tooth	
		Right	Left	Right	Left
14	3-8-95	14.8	13.5	6.9	6.7
	4-6-95	12.0	10.4	5.1	5.0
	5-8-95	9.4	7.4	3.1	2.7
	Inadequate time to include as part of the research.				
15	1-31-95	12.8	14.7	1.7	1.6
	3-27	12.0	13.4	closed	closed
16	12-12-94	10.6	11.5	4.7	5.9
	1-9-95	8.9	8.0	2.6	4.0
	1-30-95	7.4	7.3	1.6	3.2
	2-27-95	4.9	6.0	closed	1.3
	3-27-95	4.5	4.1	closed	closed
17	11-16-94	13.8	12.3	7.8	6.1
	December	Failed			
	1-11-95	11.6	7.3	5.9	2.3
	2-13-95	9.6	6.3	4.5	1.2
	3-15-95	6.7	5.0	2.4	0.4
	4-12-95	5.5	4.8	1.3	closed
	5-10-95	4.8	4.6	closed	closed

RECORD OF PATIENTS RETRACTION

NR = no records

Patient Number	Date	mm Bracket to Bracket		mm Tooth to Tooth	
		Right	Left	Right	Left
18	1-23-95	10.3	11.0	5.0	3.4
	2-27-95	7.3	8.2	3.1	1.9
	3-27-95	6.4	6.8	1.3	0.3
	5-1-95	5.2	6.7	0.4	closed
	5-23-95	4.3	6.2	closed	closed
19	Patient never showed after Jan. 1995, still leveling arches.				
20	2-15-95	8.0	8.4	2.0	2.6
	3-15-95	6.6	6.8	1.2	1.3
	4-13-95	5.1	5.6	closed	closed

PATIENTS NOT INCLUDED IN THE STUDY

#5 Retraction incomplete
#14 Retraction incomplete
#19 Retraction incomplete

TABLE 1 - EIGHT IDENTICAL ANCHORAGE PATIENTS

Patient Number	Metal Slot	Anchorage	Failed Visits	Months to Close		mm of Closure		T1 Lat Ceph PTV to Mx 6		Progress Ceph PTV to Mx 6		T1 Lat Ceph PTV to Mx 3 or 4		Progress Ceph PTV to Mx 3 or 4		% 3 or 4 Retracted	% 6 Slip
				Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
1	Right	Minimum	1	4	4	5.5	6	17.5	19	20	21	44.5	46.5	41	43	50	50
3	Right	Minimum	1	8	6	5.5	1.5	20.5	20.5	21.5	21	40.5	40.5	40	39.5	50	50
6	Right	Minimum	2	7	7	6	3.5	23.5	24.5	24	25	49	50.5	47	48	85	15
12	Left	Minimum	0	4	3	5	4	17.5	15.5	19	18	42.5	42.5	40	39.5	50	50
13	Left	Minimum	0	4	3	5.5	5.5	20	20	21.5	20.5	46	46	43	41.5	85	15
15	Right	Minimum	0	2	2	3	4.5	16.5	15	17	16.5	40.5	39.5	37	36	70	30
16	Left	Minimum	0	3	4	5	2	20	23	22.5	23.5	47	49	44	45.5	50	50
20	Left	Minimum	0	2	2	9.5	5.5	20	19.5	23	20	42.5	41.5	49	46.5	75	25

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FIGURE 1 Divider and Boley Gauge used to measure space closure.

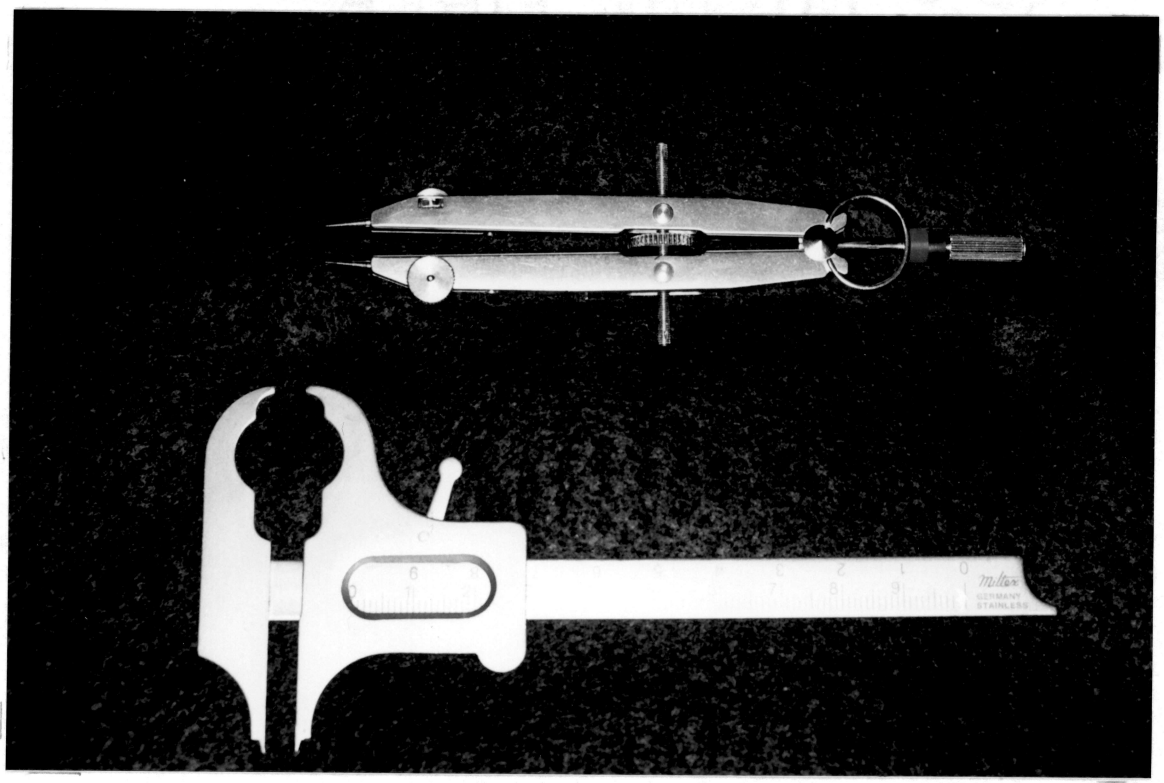


FIGURE 2 Sentalloy spring used for retraction. Dimensions used in the study were 1.5 millimeters by 1.0 centimeter.

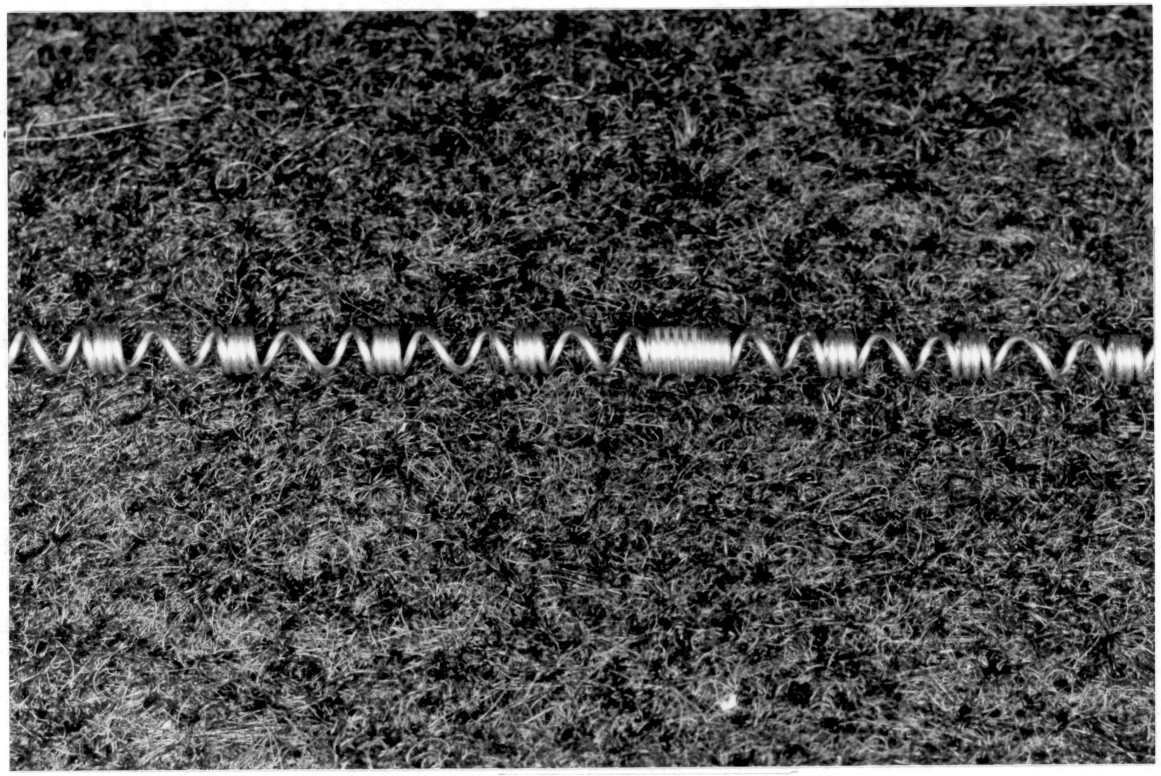


FIGURE 3 Occlusal photo of the finish model for case #13 illustrating the limited degree of rotation that has occurred after retraction was complete.

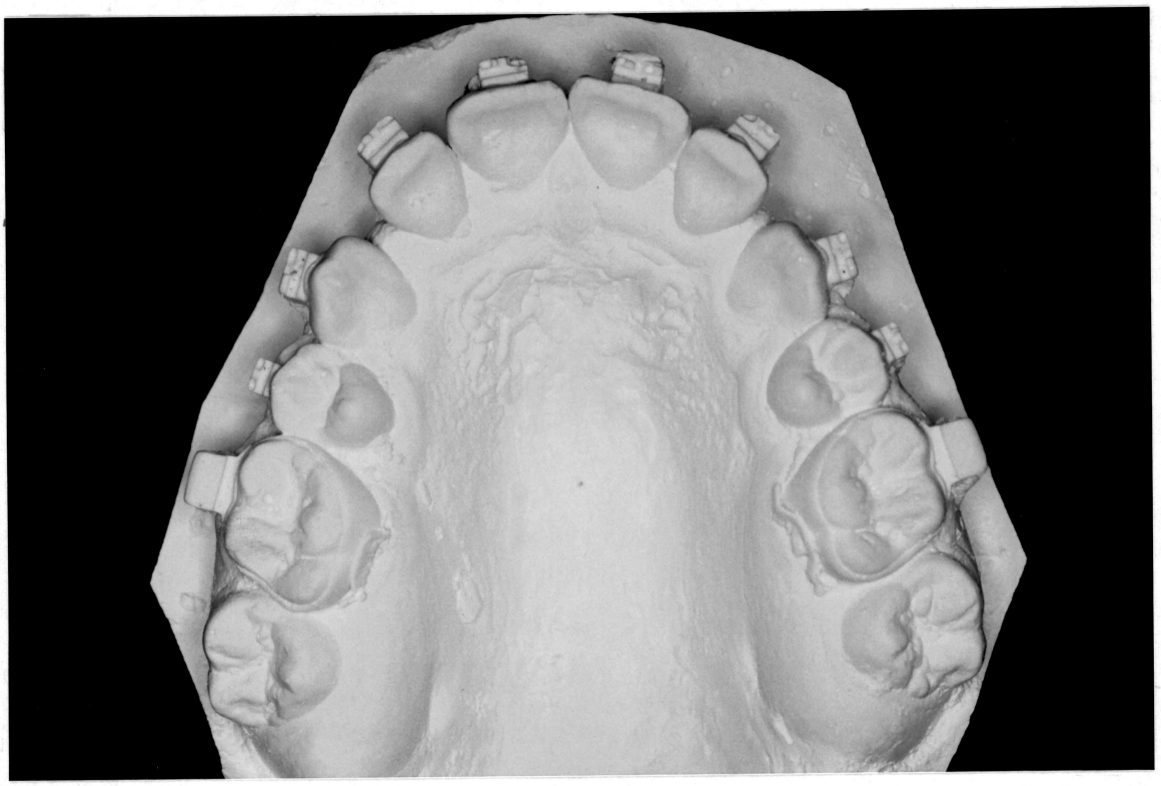


FIGURE 4 Occlusal photo of the start model for case # 15 illustrating, A) tooth to tooth measurement location and B) bracket to bracket measurement location.

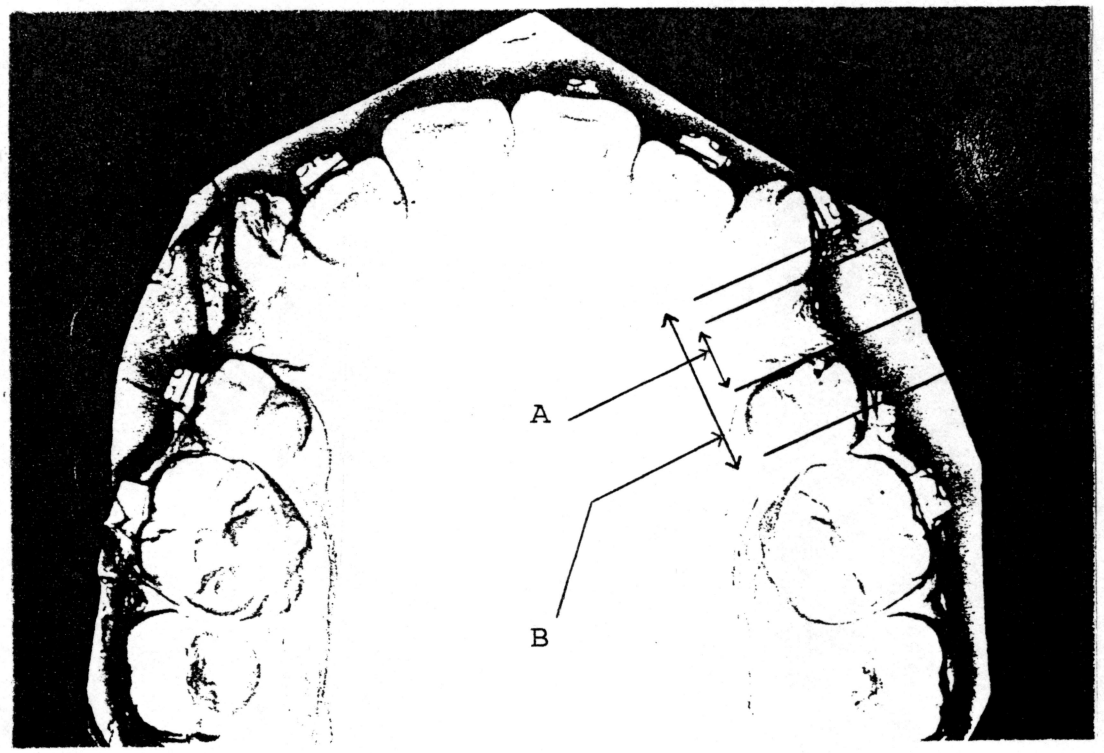


FIGURE 5 Ceramic bracket with metal insert graph showing millimeters of change per 4 week adjustment interval for patient #17. Note that visit number 2 was missed.

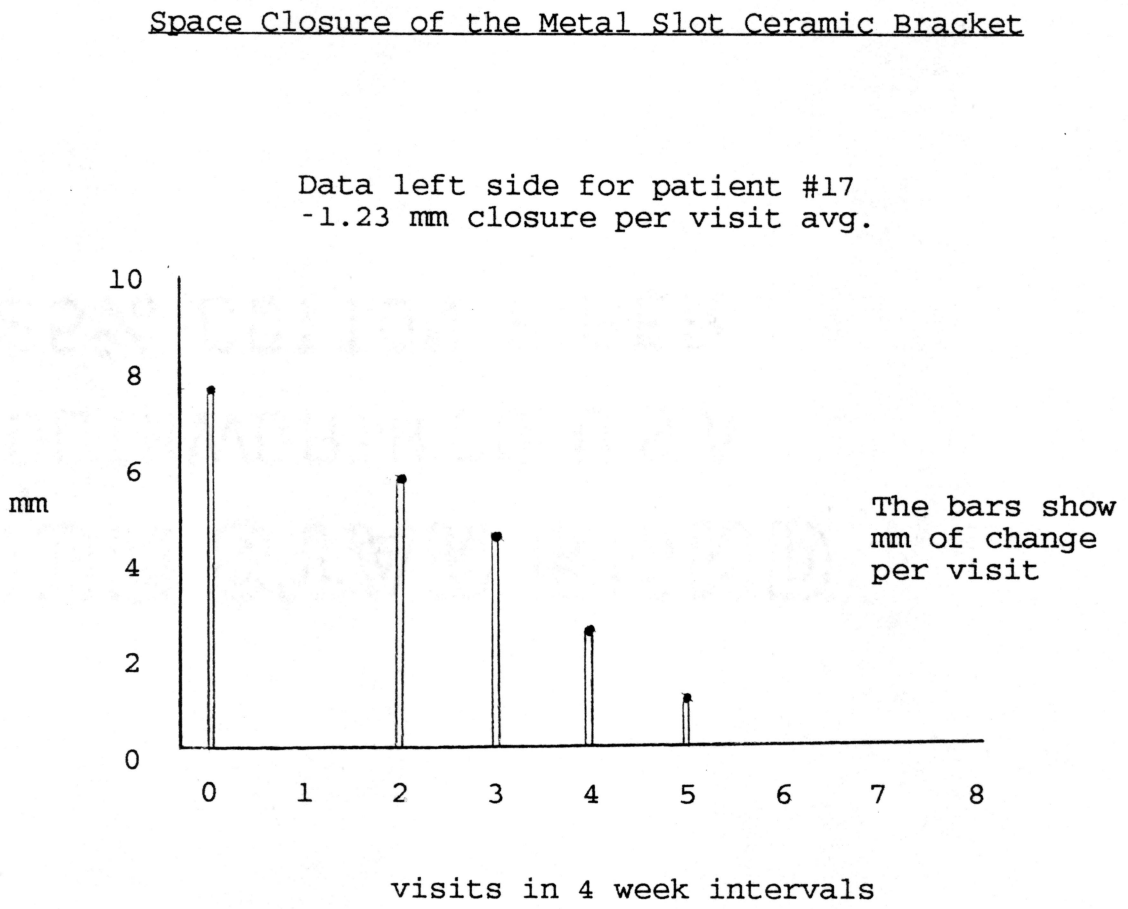
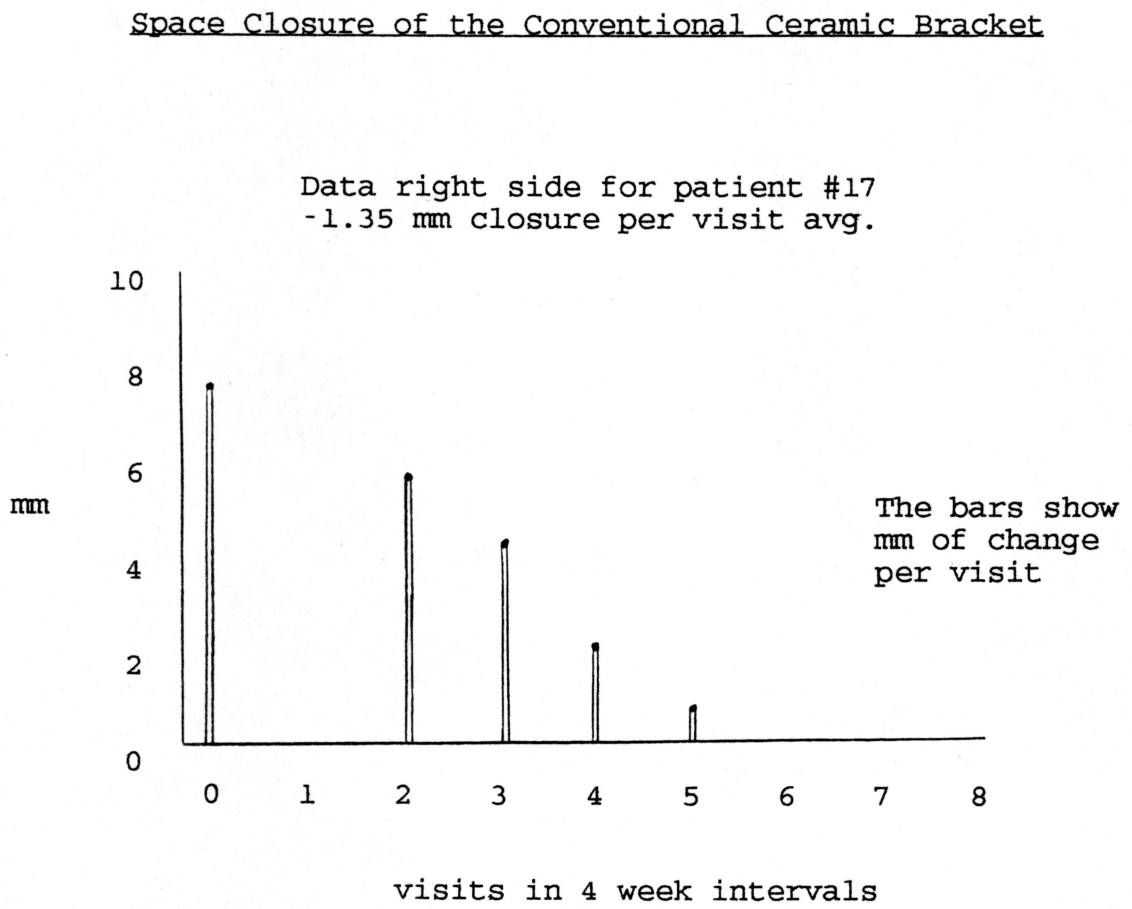


FIGURE 6 Ceramic bracket graph showing millimeters of change per 4 week adjustment interval for patient #17. Note that visit number 2 was missed.



BRACKET TO BRACKET

METAL				PORCELAIN			
Subject	Correlation Coefficient	Regression Coefficient	n	Correlation Coefficient	Regression Coefficient	n	
1	-0.53	-0.41	3	-1.00	-1.28	3	
2	-1.00	-1.35	3	-0.96	-0.69	3	
3	-0.99	-1.01	6	-0.95	-0.81	6	
4	-0.99	-0.82	4	-0.98	-1.19	4	
5	------	------	--	------	------	--	*
6	0.41	0.21	4	0.60	0.31	4	**
7	-0.97	-1.94	5	-0.98	-1.84	5	
8	-0.94	-1.29	4	-0.99	-1.52	4	
9	-0.95	-1.65	3	-1.00	-2.25	3	
10	-1.00	-1.83	3	-0.98	-1.61	3	
11	-0.99	-1.41	7	-0.98	-1.00	7	
12	-0.87	-0.91	5	-1.00	-1.12	5	
13	-0.95	-1.73	5	-0.98	-1.47	5	
14	------	------	--	------	------	--	*
15	***	-0.80	2	***	-1.30	2	
16	-0.97	-1.68	5	-0.98	-1.62	5	
17	-0.95	-1.52	5	-0.98	-1.75	5	
18	-0.98	-2.10	3	-0.95	-1.95	3	
19	------	------	--	------	------	--	*
20	-1.00	-1.40	3	-1.00	-1.45	3	

TABLE 2 Shows bracket to bracket measurements calculated as correlation coefficients and regression coefficients for each subject. The value (n) represents the number of appointments to achieve space closure.

* Represents a patient not completing the study.

** Represents a single patient whose values were not comparable with the remaining sample. His numbers were not included as 3 consecutive missed appointments where deemed the cause.

*** Represents correlation coefficients which were invalid as space closure occurred in 2 visits.

TOOTH TO TOOTH

	METAL			PORCELAIN			
Subject	Correlation Coefficient	Regression Coefficient	n	Correlation Coefficient	Regression Coefficient	n	
1	***	-0.70	2	***	-0.80	2	
2	-0.95	-1.03	4	-1.00	-0.80	3	
3	-0.99	-1.00	5	-0.93	-1.20	3	
4	***	-1.20	2	-0.97	-0.90	3	
5	------	------	--	------	------	--	*
6	-0.99	-1.25	3	-0.98	-1.20	3	**
7	***	-1.30	2	-0.94	-0.50	3	
8	-0.91	-1.55	3	-0.98	-1.12	4	
9	-0.94	-1.11	4	-0.99	-0.95	5	
10	-0.95	-1.36	4	-1.00	-1.55	3	
11	-0.99	-1.01	8	-0.99	-0.85	6	
12	-0.98	-0.92	4	-1.00	-0.76	5	
13	-1.00	-1.40	4	-0.99	-1.26	5	
14	------	------	--	------	------	--	*
15	***	-0.70	2	***	-1.60	2	
16	-0.99	-1.45	5	-0.99	-1.51	4	
17	-0.96	-1.23	5	-0.99	-1.35	6	
18	-0.97	-1.18	4	-1.00	-1.68	4	
19	------	------	--	------	------	--	*
20	-1.00	-1.30	3	-0.99	-1.00	3	

TABLE 3 Shows tooth to tooth measurements calculated as correlation coefficients and regression coefficients for each subject. The value (n) represents the number of appointments to achieve space closure.

* Represents a patient not completing the study.
** Represents a single patient whose values were not comparable with the remaining sample. His numbers were not included as 3 consecutive missed appointments where deemed the cause.
*** Represents correlation coefficients which were invalid as space closure occurred in 2 visits.