Long-Term Stability of Dental Relationships After Orthodontic Treatment

MICHAEL D. UHDE, CYRIL SADOWSKY AND ELLEN A. BEGOLE

Dr. Uhde is in the private practice of orthodontics in Harrison, Ohio. He holds a D.M.D. degree from the University of Louisville and an M.S. degree in Orthodontics from the University of Illinois.

Dr. Sadowsky is an Associate Professor in the Department of Orthodontics, College of Dentistry, University of Illinois in Chicago. He holds a B.D.S. degree from the University of Witwatersrand, Johannesburg, South Africa and an M.S. degree in Orthodontics from the University of Illinois.

Dr. BeGole is an Associate Professor of Biostatistics in the Department of Orthodontics, University of Illinois in Chicago. She is a graduate of the University of Michigan, with an M.S. degree from Columbia University and Ph.D. degree from the University of Pittsburgh.

Address:
Dr. Cyril Sadowsky
Department of Orthodontics
College of Dentistry
University of Illinois in Chicago
801 S. Paulina Street
Chicago, IL 60612

Adult changes in selected occlusal parameters are measured, with the study sample limited to 72 subjects with a history of malocclusion treated orthodontically 12 to 35 years previously. Variations were large. Most of the corrections were retained, with mean changes tending toward pretreatment values.

Angle[1] maintained that orthodontic correction will remain stable if the teeth are aligned into a normal occlusion and provided with adequate retention and vigorous masticatory function. However, orthodontists have observed that their treatment results are susceptible to at least as much change as untreated occlusions, and that there certainly are limitations in the long-term stability of corrected relationships.

Many studies have investigated the changes in the occlusion and dental relationships after orthodontic treatment. Most of these have been limited to short-term evaluations soon after orthodontic treatment, when the occlusion is most subject to change.

The purposes of this study were:

1. To determine whether posttreatment changes in dental relationships are related to the Angle class of original malocclusion.

2. To determine whether posttreatment changes in dental relationships are related to extraction of teeth in

conjunction with the orthodontic treatment.

3. To identify possible relationships between treatment changes and posttreatment changes.

4. To evaluate interactions between changes in a number of variables with mandibular arch crowding during the posttreatment period.

Materials and Methods

Sample Description

As part of a previous study by Sadowsky and BeGole[2] on the long-term effects of orthodontic treatment, records of approximately 1800 orthodontically treated cases had been selected from five orthodontic practices in the Chicago area. All had been treated with a full-banded edgewise appliance prior to adulthood.

A Hawley-type removable retainer had been used in the maxillary arch and a fixed lingual retainer in the of time. Retention had been discontinued at least twelve years prior to mandibular arch for varying lengths the study.

An effort was made to contact all 1800 former patients. Of those responding, 158 were willing to participate in that study, and examinations and follow-up records were finally made on 96.

For this study, 72 were selected from the 96 available sets of records on the basis of the following additional criteria:

1. A full complement of permanent teeth, either erupted or unerupted, prior to treatment.

2. No teeth from first molars forward lost since the end of orthodontic treatment.

3. Angle Class I or II pretreatment malocclusion.

The distributions of pretreatment Angle class of malocclusion and therapeutic extraction are shown in Table 1.

TABLE 1
Sample distribution

Original Malocclusion	*Extraction*	*Non-Extraction*
Class I	18	18
Class II	9	27
Total	27	45

Four first or second bicuspids had been extracted in those designated as extraction cases.

Average time out of retention was 20 years, with a range of 12 to 35 years.

Data Recording

Standardized photographs were made of the pretreatment, posttreatment and long-term follow-up dental casts, and a number of landmarks on each view were digitized for subsequent computer analysis as previously described by BeGole *et al.*[3] The following ten variables were evaluated:

a. Anteroposterior relationship of the left maxillary to mandibular molar.

b. Anteroposterior relationship of the right maxillary to mandibular molar.

c. Overjet

d. Overbite

e. Maxillary intercuspid width

f. Mandibular intercuspid width

g. Maxillary intermolar width

h. Mandibular intermolar width

i. Maxillary arch crowding

j. Mandibular arch crowding

Data Analysis

Mean and standard deviation were calculated for each variable at each treatment stage—pretreatment (A), posttreatment (B) and follow-up (C)—and the mean change in each after

treatment was then computed. Multivariate analysis of variance was applied to identify any statistically significant difference between Class I and Class II cases or between extraction and non-extraction therapy.

Correlation coefficients were used to relate the posttreatment changes to the changes occurring during treatment for all ten variables.

Correlation coefficients were also computed among all the variables in the posttreatment stage.

Multiple regression analyses were applied to evaluate the degree to which the variability in mandibular arch crowding after treatment could be related to posttreatment changes in the other nine variables.

Findings

The mean values for mandibular intercuspid width, overbite, overjet and mandibular crowding from the pretreatment (A) to the posttreatment (B) to the long-term postretention (C) stages are graphically shown for the 45 non-extraction cases in Fig. 1 and for the 27 extraction cases in Fig. 2. More detailed statistical analyses of the changes for each of the variables follow (Tables 2-4).

Molar Relationship

The mean posttreatment change for the molar relationship was always toward Class II; however, these changes were small, with the mean change less than 0.50mm in most sample groups. The greatest mean change was 1.05mm on the right side in Class II extraction cases. No statistically significant difference in the anteroposterior molar change after treatment was detected between any of the sample groups.

TABLE 2

Changes during the post-treatment period (C-B)*

Variable	*Class I*				*Class II*			
	mm change		*mm change*		*mm change*		*mm change*	
	Non-extraction		*Extraction*		*Non-extraction*		*Extraction*	
	Mean	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*
Molar Relationship								
Left	0.44	0.99	0.22	1.10	0.24	0.74	0.68	0.85
Right	0.19	0.89	0.07	0.90	0.67	1.22	1.05	1.17
Overjet	0.33	1.28	0.67	1.21	1.11	1.25	0.57	1.26
Overbite	0.94	1.40	1.16	1.14	1.60	1.75	1.02	1.35
Intercuspid Width								
Maxilla	—2.22	1.54	—1.74	1.74	—0.88	2.05	—2.04	1.82
Mandible	—2.53	1.77	—2.07	1.33	—2.08	1.78	—2.25	1.30
Intermolar Width								
Maxilla	—1.30	1.68	—1.12	1.77	—1.35	1.96	—2.19	1.84
Mandible	—1.45	1.91	—1.05	1.49	—0.74	1.87	—1.69	1.97
Crowding								
Maxilla	—0.42	0.81	—0.25	0.39	—0.24	0.59	—0.50	0.75
Mandible	—1.17	0.99	—1.23	1.07	—1.07	1.11	—1.33	0.79

* Not significant ($p > 0.05$).

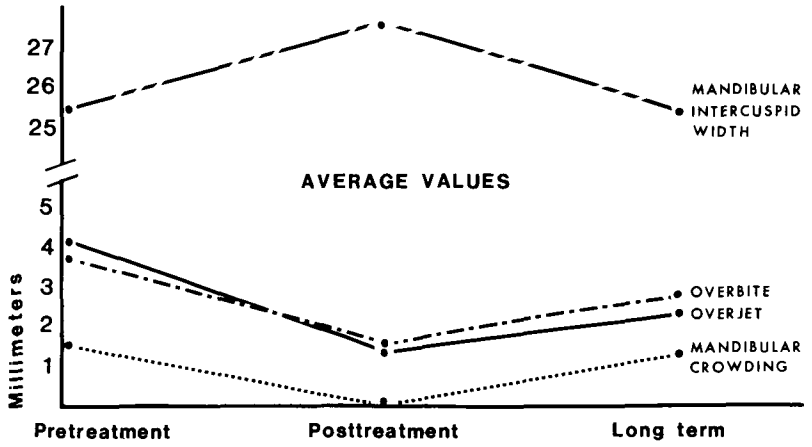

Fig. 1 Mean values for mandibular intercuspid width, overbite, overjet and mandibular crowding for 45 non-extraction cases before treatment and short and long-term posttreatment. Standard deviations for all values were higher than the mean changes. See Tables 2-4.

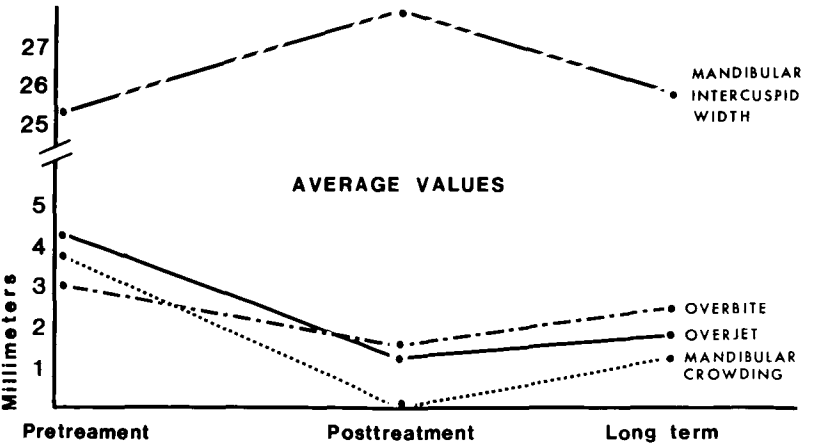

Fig. 2 Mean values for mandibular intercuspid width, overbite, overjet and mandibular crowding for 27 extraction cases before treatment and short and long-term posttreatment. Standard deviations for all values were higher than the mean changes. See Tables 2-4.

Overjet

A tendency for the overjet to increase was seen in all groups, with a slightly greater increase in the Class II group. The mean posttreatment overjet increase was 0.50mm in the Class I cases and 0.97mm in the Class II. Mean overjet increase in the nonextraction cases was 0.80mm, compared to 0.63mm in the extraction cases. None of these differences was statistically significant at the $p < .05$ level.

Overbite

Overbite behaved much like overjet, with mean increases of 1.05mm in Class I, 1.45 mm in Class II, 1.34mm with extraction and 1.11mm without extraction.

Maxillary Intercuspid Width

Intercuspid width tended to decrease in all sample groups, again with no statistically significant differences. Mean decreases were 1.98mm in Class I, 1.17mm in Class II, 1.84mm with extraction and 1.42mm without extraction.

Segregating extraction categories by malocclusion class showed a small change of 0.88mm in the non-extraction Class II cases, compared to 2.04mm in the Class II extraction cases. The opposite was observed in Class I, where largest mean decrease of 2.22mm was found in the nonextraction group, versus 1.74mm in the extraction group.

Although all groups experienced a mean decrease in maxillary intercuspid width after treatment, none of the decreases equalled the increase achieved during treatment.

Mandibular Intercuspid Width

Even greater decreases were found in the mandibular intercuspid width,

TABLE 3

Changes during the post-treatment period in each malocclusion group*

Variable	*Class I* mm change Mean	S.D.	*Class II* mm change Mean	S.D.
Molar Relationship				
Left	0.33	1.04	0.34	0.78
Right	0.13	0.89	0.77	1.20
Overjet	0.50	1.24	0.97	1.26
Overbite	1.05	1.27	1.45	1.66
Intercuspid Width				
Maxilla	—1.98	1.64	—1.17	2.04
Mandible	—2.30	1.56	—2.12	1.66
Intermolar Width				
Maxilla	—1.21	1.71	—1.56	1.94
Mandible	—1.25	1.70	—0.97	1.92
Crowding				
Maxilla	—0.33	0.63	—0.31	0.64
Mandible	—1.20	1.02	—1.14	1.03

* Not significant ($p > 0.05$).

TABLE 4

Changes during the post-treatment period in the extraction and non-extraction treatment groups*

Variable	*Non-extraction* mm change Mean	S.D.	*Extraction* mm change Mean	S.D.
Molar Relationship				
Left	0.32	0.84	0.37	1.03
Right	0.48	1.12	0.40	1.09
Overjet	0.80	1.31	0.63	1.20
Overbite	1.34	1.64	1.11	1.19
Intercuspid Width				
Maxilla	—1.42	1.96	—1.84	1.74
Mandible	—2.26	1.77	—2.13	1.30
Intermolar Width				
Maxilla	—1.33	1.84	—1.48	1.83
Mandible	—1.02	1.90	—1.26	1.66
Crowding				
Maxilla	—0.31	0.69	—0.33	0.54
Mandible	—1.11	1.05	—1.27	0.97

* Analysis of variance not significant ($p > 0.05$).

but again the analysis of variance indicated no statistically significant difference among the sample groups. The intercuspid distance in the mandibular arch decreased almost to or past the original intercuspid width in all of the sample groups.

Mean decreases were 2.30mm in Class I, 2.12mm in Class II, 2.13mm for both classes with extraction and 2.26mm without extraction. The extraction and non-extraction cases in each malocclusion experienced similar changes after treatment.

Maxillary Intermolar Width

The tendency for the maxillary intermolar width to decrease was similar in all sample groups. Mean values were 1.21mm in Class I, 1.56mm in Class II, 1.48mm with extraction and 1.33mm without extraction. The largest decrease was 2.19mm found in Class II extraction cases, somewhat more than the 1.35mm found for non-extraction Class II.

Mandibular Intermolar Width

Mean mandibular intermolar width also decreased after treatment in all sample groups, again with no statistically significant difference among them.

Decreases were 1.25mm in Class I, 0.97mm in Class II, 1.22mm with extraction and 1.02mm without extraction. The Class II extraction cases again showed a slightly larger mean decrease of 1.69mm compared to 0.74mm in the Class II non-extraction cases.

Maxillary Crowding

A tendency was found for the maxillary arch to develop minor crowding after treatment, again with no statistically significant difference among sample groups. Space deficiencies averaged 0.33mm in Class I, and 0.31mm in Class II, with extraction and non-extraction cases showing similar deficiencies.

Mandibular Crowding

There was more posttreatment crowding in the mandibular arch, with a mean deficiency of 1.20mm in Class I, 1.14 in Class II, 1.27mm with extraction and 1.11 without extraction. Once more, only minor differences were found between extraction and non-extraction in both Class I and Class II groups.

Relation to Treatment Changes

Tests of significance were applied to determine whether posttreatment change was significantly correlated to any treatment change (Table 5).

Analysis of the ten variables produced eleven statistically significant intercorrelations between treatment changes and the posttreatment changes of specific variables.

A significant positive correlation was found between the change in molar relationship on the right side during treatment and its relapse in the posttreatment period.

A significant correlation was also found between the amount of overbite reduction occurring during treatment and the increase in overbite after treatment.

Maxillary intercuspid width increase during treatment and the amount of posttreatment maxillary arch crowding were significantly correlated.

Maxillary arch crowding after treatment was less than the reduction of crowding accomplished during treatment, but still statistically correlated.

Increase in the intermolar width of either arch during treatment was significantly correlated with a decrease

TABLE 5

Correlation coefficients between all variables for treatment vs. posttreatment changes.

	Molar Relationship				*Intercuspid Width*		*Intermolar Width*		*Crowding*	
	Left	*Right*	*Overjet*	*Overbite*	*Max.*	*Mand.*	*Max.*	*Mand.*	*Max.*	*Mand.*
Molar Relationship										
Left	−0.08	−0.04	0.15	−0.01	0.05	0.02	0.16	0.13	−0.01	−0.12
Right	−0.20	−0.36*	0.03	−0.12	0.08	0.08	0.24	0.20	−0.10	−0.02
Overjet	−0.11	−0.09	−0.04	−0.16	0.01	0.22	0.23	0.13	−0.18	0.14
Overbite	0.00	−0.05	−0.02	−0.42*	0.00	−0.03	−0.01	0.19	−0.16	0.05
Intercuspid Width										
Maxilla	−0.06	−0.22	0.07	−0.07	−0.48*	−0.11	0.03	−0.17	−0.38*	−0.23
Mandible	0.03	−0.05	0.06	−0.01	−0.38*	−0.29*	−0.11	−0.36*	−0.06	−0.05
Intermolar Width										
Maxilla	0.25	0.06	−0.14	−0.22	0.03	0.10	−0.55*	−0.30*	−0.07	0.20
Mandible	0.25	0.07	−0.09	−0.23	0.00	0.06	−0.25	−0.44*	−0.12	0.18
Crowding										
Maxilla	0.11	−0.07	0.05	−0.13	−0.09	−0.02	0.02	−0.07	−0.31*	−0.07
Mandible	0.16	0.14	0.14	−0.07	−0.05	0.00	0.00	−0.18	−0.20	−0.08

* Statistically significant $p < 0.05$

TABLE 6

Correlation coefficients between all variables for changes during the post-treatment period.

	Molar Relationship				*Intercuspid Width*		*Intermolar Width*		*Crowding*	
	Left	*Right*	*Overjet*	*Overbite*	*Max.*	*Mand.*	*Max.*	*Mand.*	*Max.*	*Mand.*
Molar Relationship										
Left	1.00									
Right	0.12	1.00								
Overjet	−0.10	0.32*	1.00							
Overbite	−0.17	0.09	0.47*	1.00						
Intercuspid Width										
Maxilla	−0.04	−0.09	0.28	0.25	1.00					
Mandible	0.03	−0.07	0.09	−0.09	0.56*	1.00				
Intermolar Width										
Maxilla	−0.18	−0.36*	−0.21	0.01	0.19	0.17	1.00			
Mandible	−0.11	−0.22	0.06	0.14	0.36*	0.44*	0.63	1.00		
Crowding										
Maxilla	0.07	−0.15	0.11	0.17	0.38*	0.01	0.25	0.18	1.00	
Mandible	0.29*	0.08	0.05	−0.04	0.28*	0.39*	0.19	0.36*	0.25	1.00

* Statistically significant $p < 0.05$

in that dimension after treatment. Width of upper and lower arches also appeared interrelated, in that an increase in the intermolar width in the maxillary arch was correlated with a reduction in the mandibular intermolar width after treatment.

Relationships Between Posttreatment Changes

Tests of significance were carried out on all variables representing changes occurring after treatment, to determine whether a posttreatment change in one variable was significantly correlated to posttreatment changes in any of the others (Table 6).

Statistical analysis of the ten variables produced the following twelve statistically significant intercorrelations of posttreatment changes.

As the molar relationship on the right side of the arch changed toward its original value after treatment, the mean maxillary intermolar width was found to decrease and the overjet to increase toward their original values.

On the left side, as the molar relationship changed toward Class II, the mean overall mandibular arch crowding was found to increase. Those are the vagaries of statistical correlations.

A positive correlation was found between posttreatment increases in overbite and overjet.

After treatment the upper and lower arch width tended to decrease in both molar and cuspid regions, with a positive correlation between the two.

An expected positive correlation was also found between the maxillary and mandibular width changes.

The decreases in maxillary intermolar and intercuspid width were also positively correlated with crowding in both arches.

Mandibular Arch Crowding

The degree to which the other nine variables taken together relate to the variability of mandibular arch crowding after treatment was evaluated by a multiple regression analysis. Posttreatment changes in each variable were introduced into the equation until a maximum amount of mandibular arch crowding variability was introduced.

The square of the R values reflects the percentage of variability accounted for in the system. On this basis, 41% of the variability of mandibular arch crowding can be related to the other nine variables, so 59% of the variability of mandibular arch crowding must be unrelated to the variables considered in this study. The proportional breakdown into the posttreatment change of each variable and its corresponding square of R value may be seen in Table 7.

The multiple regression indicated that posttreatment change of the man-

TABLE 7

Multiple regression for the relationship between mandibular arch crowding and a set of other variables

Variable	*Cumulative R Value*	*Cumulative percentage of variability*
Intercuspid Width Mandible	.353	12.47
Molar Relationship (Left)	.482	23.22
Crowding—Maxilla	.525	27.58
Molar Relationship (Right)	.567	32.13
Overjet	.604	36.47
Intermolar Width Maxilla	.626	39.15
Intercanine Width Maxilla	.640	40.98

dibular intercuspid width was most prominently related to mandibular arch crowding, with a 12.5% relationship.

Discussion

The sample of 72 cases used in this study was larger than those in previously reported studies. Class I and Class II malocclusion groups were equally distributed, with bicuspid extractions in one fourth. The minimum postretention period of twelve years in this sample was much longer than in other studies, allowing more time for full expression of posttreatment change. The finding of only about 0.5mm change in the molar relationship toward Class II supports Hechter's[4] findings of the relative stability of the molar relationship.

The posttreatment changes in overjet were similar to those observed by Amott,[5] Bresonis and Grewe,[6] and Bishara *et al,*[7] in that each malocclusion group maintained a net decrease in overjet from pretreatment levels in spite of a tendency toward an increase after treatment.

The posttreatment changes in overjet were unrelated to the type of original malocclusion. These findings were similar to those reported by Rose[8] and El-Mangoury.[9] Conflicting findings were observed by Bresonis and Grewe,[6] Hechter[4] and Little *et al,*[10] who reported that the Class II, Division 1 cases showed a greater relapse in overjet after treatment than other malocclusion types.

Overbite changes recorded in this study were consistent with others reported in the literature, in that the overbite was decreased during treatment and had a tendency to increase slightly after treatment.[7-16]

An exception is Amott's[5] observations of 55 non-extraction cases in which overbite decreased during treatment continued to decrease after treatment. Hernandez[14] and Hechter[4] maintained that the overbite in extraction cases exhibited a stronger tendency to increase after treatment than in non-extraction cases.

In this study, although a mean decrease in the overbite was observed, a statistically significant correlation existed between the amount of overbite decrease achieved in treatment and the increase observed after treatment. This finding suggests that the deeper overbite cases should be overtreated in anticipation of relapse during the posttreatment period as suggested by some other authors.[17-20]

It is in opposition to Bresonis and Grewe's[6] report that posttreatment overbite increased the least in Class I and Class III cases, and the most in Class II, Division 1 cases.

Hechter[4] maintained that it was the Class II, Division 2 cases, and not the Class II, Division 1 cases, that experienced the greatest overbite increase after treatment. Due to the small size of the Class II, Division 2 subsample in the present study, it was not possible to statistically compare these groups.

The statistically significant correlation between increase in overjet and overbite after treatment found in this study was not observed by Amott.[5]

Mean intercuspid width in both arches was increased during treatment in all categories, and decreased after treatment toward its original width. This was also reported by Dona,[15] Riedel,[17] Amott,[5] Arnold,[21] Welch,[22] El-Mangoury[9] and Little, *et al.*[10]

Mandibular intercuspid width was found to decrease close to or past the

original intercuspid dimension. There was no significant net mean increase in mandibular intercuspid width in any sample group, which is in agreement with a number of previous studies.[4,23,24]

However, Walter[11,25] maintained that 62% of his extraction cases sustained an average increase of 1.4mm in the mandibular intercuspid width and 62% of his non-extraction cases sustained an overall increase of 2.0mm in the mandibular intercuspid width over an average postretention time of 2 years. Herberger[26] reported that 68% of his sample of non-extraction cases maintained some intercuspid width expansion from 4 to 6 years postretention. Little, *et al*[10] also reported that a net increase in mandibular intercuspid width will persist more than 10 years after retention in some cases.

Davis[28] reported 63% of extraction cases maintaining a net intercuspid width increase, compared to only 32% of non-extraction cases. However, such statistically significant differences between the posttreatment changes of maxillary or mandibular intercuspid width as also reported by a number of previous authors[4,21,27] were not found in either extraction or non-extraction cases in this study.

No significant difference was found in the behavior of intercuspid width in different malocclusion groups, supporting the findings of Arnold,[21] Welch,[22] and Davis.[28] Evidence suggesting that Class II, Division 2 cases are better able to maintain expansion of mandibular intercuspid width has been reported,[5,23] but Hechter[4] found no significant difference between Class II, Division 2 cases and other malocclusion groups. Again, because of the small number of Class II, Division 2 cases in this sample, all Class II malocclusions were evaluated as one group.

Net increase in intercuspid width was more long-lasting in the maxillary arch, as also reported by Rose,[8] Bishara *et al*[7] and Sondhi *et al*.[24] This evidence reinforces the postulate of McCauley[29] and others that the intercuspid width dimension should not generally be violated, and that the mandibular intercuspid width be used as a guide around which to build the maxillary arch.

The statistical analysis also revealed a tendency toward a decrease of maxillary and mandibular intermolar widths that had been increased during treatment.

Non-extraction cases maintained a greater net increase in the intermolar width than extraction cases. These findings are similar to those of Walter,[11,25] Arnold,[21] Welch,[22] Rose[8] and Shapiro.[23] No statistically significant difference was found between the relapse tendencies of the maxillary and mandibular intermolar widths in Class I and Class II malocclusions, similar to the findings of Rose.[8]

Overall, the maxillary and mandibular arches of all groups tended to undergo crowding after treatment, but never to the degree of the original pretreatment crowding. However, Davis[28] reported that extraction cases experienced less mandibular incisor crowding and were more stable than non-extraction cases after treatment.

Multiple regression analysis considering only posttreatment changes found the small 12.5% association of the mandibular intercuspid width with mandibular crowding to be the most significant relationship.

Conclusions

1. For the variables recorded, dental relationships tended to return

toward their pretreatment values after treatment, while still retaining a major part of the correction.

2. Changes in some variables tended to be more stable than others.

3. Although anteroposterior molar relationships tended to shift toward Class II after treatment, they were relatively stable in both Class I and Class II cases and unrelated to extraction therapy.

4. Intermolar and intercuspid width increases persisted more in the maxillary arch than in the mandibular arch. In both arches, intertooth width increases were least tolerated in the cuspid region regardless of the type of malocclusion or extraction therapy.

5. Although most relapse tendencies were the same for the extraction and non-extraction cases, much of the intermolar width increase in the non-extraction cases was maintained. In the extraction cases, the mean intermolar width was only slightly increased during treatment, and decreased beyond the original intermolar width after treatment.

6. Posttreatment decreases in width of the maxillary and mandibular arches were directly related to each other.

7. Overbite tended to increase after treatment, with the amount of overbite increase statistically correlated ($p < 0.05$) to the amount of overbite reduction during treatment. The relapse tendency was unaffected by the type of original malocclusion or extraction therapy.

8. As the overbite increased after treatment, the overjet also tended to increase.

9. The maxillary and mandibular arches tended to become more crowded after treatment, with no difference found between the malocclusion groups or extraction therapy. The maxillary arch developed slightly less crowding than the mandibular arch.

10. The mandibular arch in all of the sample groups was observed to lose width after treatment, with concomitant crowding. Multiple regression analysis indicated that the post-treatment changes in other dental relationships evaluated in this study were related to only 41.0% of the variability of mandibular crowding, with the decrease in intercuspid width accounting for the most (12.5%).

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