AN EVALUATION OF THE OCCLUSION IN POST-ORTHODONTIC PATIENTS

by

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GRADUATE STUDIES

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Date May 12, 1977

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Abstract

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Orthodontists are becoming increasingly more aware that proper functional occlusion is an integral part of treatment. Interferences which a patient may exhibit at the end of orthodontic therapy are a potential cause for severe complications in his later life. The patient should not be dismissed until the stability of the dentition and the health of the supporting structures can be assured.

This investigation was performed to assess the static and functional occlusal status of post-orthodontically treated patients. Forty patients, who had received orthodontic treatment at Case Western Reserve University and were out of retention at least five years, were examined. Forty additional patients, who had not received any orthodontic treatment and were to serve as a control group,

were similarly examined. Twenty-eight variables were observed in each patient, and noted according to a method adapted from existing indices.

Relationships were established between the two samples and within each one. A series of analyses, including univariate F tests and correlation coefficients, were performed to indicate which variables were statistically significant. Another series of analyses, including multiple regression and discriminant functions, were performed to indicate which combination of variables best discriminated among the samples.

The results of the study may be summarized:

1. There was statistically more overbite, overjet, and muco-gingival problems in the orthodontically treated sample than in the control group.

2. There was statistically more bruxing, protrusive interferences, wear facets on teeth, and anterior crowding in the maxillary arch in the control group than in the treated group.

3. 40% of the orthodontically treated patients and 37.5% of the control group had poor intercuspation.

4. "Group function occlusion" was demonstrated in 50% of the control group, and only in 25% of the treated group.

5. A slide from centric relation to centric occlusion of 1 mm or less was evident in 47.5% of each sample.

6. Approximately 75% of the patients had non-working interferences; however, 60% of the interferences involved second molars in both groups.

7. TMJ symptoms were more prevalent in the orthodontically treated group (37.5%) than in the control group (20%).

8. The amount of anterior crowding in the maxillary arch was significantly related to the amount of anterior crowding in the mandibular arch.

9. Variables for overbite and protrusive interferences were significantly related.

10. Variables for wear facets on cuspids and TMJ symptoms were significantly related in the treated group.

11. Variables for a centric relation slide and a bruxing history were significantly related in the control group.

12. Variables for lateral excursive function, bruxing history, TMJ symptoms, mid-lines coinciding, and

muco-gingival problems, in combination with one another, were capable of best discriminating the patients into the two groups.

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DEDICATED TO

My wife, Brenda,

and

children, Marnie and Neal,

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INTRODUCTION

Orthodontic treatment is usually initiated for esthetic or functional demands. Among the objectives of treatment, the achievement of optimal functional occlusion and the maintenance of the periodontal health are of primary importance. Orthodontic treatment is hardly justified if the end result exists with functional disturbances which may later contribute towards disorders of the stomatognathic system.

Few, if any, studies have been done to objectively compare a post-orthodontically treated sample to an untreated population.

The objectives of this investigation are:

1. To evaluate and compare the static and functional occlusal status of two groups; one consisting of forty post-orthodontically treated patients at least five years out of retention, and the other group consisting of forty untreated people.
2. To investigate the significance of the relationships of the variables observed.
3. To statistically analyze factors which can distinguish a treated patient from an untreated patient.

REVIEW OF THE LITERATURE

Orthodontic literature has tried to explain the importance of gnathological principles as it relates to every treated patient. The practical concept of an ideal occlusion that recognizes the interplay between the temporomandibular joints, teeth, and the neuromuscular system is feasible and should be the basis for the treatment of every orthodontic problem (Timm et al, 1976). Harmony is obtained between all the components of the masticatory system by providing for unrestricted lateral movements, occlusal stability in centric relation, centric occlusion, and between (freedom of centric), and the absence of occlusal interferences in centric relation and in protrusive, working, and balancing movements (Beyron, 1969). Kessler's (1976) model of an ideal occlusion is exemplified by a normal mesiodistal relation and interdigitation of the cusps of the posterior teeth; with an acceptable overbite, overjet, and incisal guidance of anterior teeth in well developed and well aligned dental arches.

There are several basic concepts of occlusion utilized throughout dentistry. "Bilateral balanced occlusion" is most efficiently used in complete denture patients (Yurkstas, 1954). This scheme has contacts on all the teeth in working, balancing, and protrusive

excursions. "Canine protected occlusion" is a concept developed by D'Amico (1958) which has only canine contact in lateral excursions. Stuart and Stallard (1960) using gnathological principles, developed "mutually protected occlusion". In this scheme, the cuspids prevent injuries to the buccal cusps of the posterior teeth during lateral excursions, and the anterior teeth protect the cusps of the posterior teeth in the incisive position (Weinberg, 1964). Beyron (1964) describes "group function" in which there is always a group of teeth protecting other teeth. In lateral positions, occlusal contacts are present on several teeth on the working side only, and during a protrusive movement, there is always a group of anterior teeth in contact. Ingervall (1976) believes that "group function occlusion" is the most common and that this should be the aim of orthodontic treatment.

There has been much controversy on the subject of whether centric relation and centric occlusion should coincide. Poulton (1969), Sandusky (1971), Graber (1954), Schuyler (1947), Roth (1972), and Jankelson (1960) agree that the positions should coincide. Ahlgren and Posselt (1963), Stallard (1964), Cohen (1965), and Timm et al (1976), state that these positions usually do not coincide after orthodontic treatment.

The orthodontist has an advantage over fellow dentists since he has complete control over each and every

tooth in the dental arches, and so can position the tooth upright over basal bone so that the resultant of the occlusal forces is directed along the long axis of the teeth (Coleman, 1948). He further states that when going into protrusive excursion, there should be ease of motion from centric to protrusive with no interferences. In lateral, it is important to have simultaneous contact on as many teeth as possible on the working side, and no interferences on the balancing side.

Stillman (1925) observed that traumatic occlusion occurs when a tooth whose cusps are out of harmony with other cusps, will receive abnormally heavy stress during occlusal function. Stahl (1970) defines occlusal trauma as that force or forces caused by mandibular movement and resultant tooth percussion capable of producing pathologic changes in the periodontium. Prematurities exist in mouths with good occlusion and in mouths with orthodontically treated occlusion (Cohen, 1965).

The neuromuscular reaction to the impulses from an interfering tooth may then be almost contrary to the usual reaction in chewing. Instead of such a tooth area being avoided, there is a tendency to seek out the interfering tooth and brux. This is usually subconsciously done, and the forces are extremely powerful. The excessive occlusal loading produced may be a contributing cause of damage to the supporting tissues in periodontal disease (Beyron,

1969).

Youdelis (1965) cited over fifteen references stating harmful effects due to balancing side interferences. Roth (1973), Timm et al (1976), and Williams (1976) believe that balancing side interferences develop in orthodontically treated patients from inadequate maxillary molar lingual crown torque, or by not banding second molars at all.

Several authors have written papers emphasizing the importance of gnathologic concepts, and the need for equilibration of treated cases. Fifty years ago, Arnold (1926) pointed out that just as crowns, bridges, and restorations should be kept under surveillance for some time after their insertion to detect a possible trauma, so also should cases of malocclusion that have been corrected by orthodontic treatment be carefully examined from time to time. It means nothing to study the cases from plaster models in a position of rest; normal occlusion must deal with the relation of the inclined planes during the function of mastication. Thompson and Craddock (1949) stated that orthodontists are no longer satisfied with a beautiful face in the presence of a locked occlusion which is not only insufficient in mastication, but may lead in later years to periodontal destruction, temporomandibular joint dysfunction, or other pathologic changes. Hoover (1967) emphasized that the orthodontists responsibility should not end until the occlusion is such that continued periodontal health is

assured. This may require the equilibration of the occlusion, or selective restorative work to improve contours, close contacts, and improve marginal ridge height following orthodontic therapy. Occlusal equilibration enables the dentist to distribute the forces delivered to and through the teeth to the maximum number of teeth, thus reducing the forces on individual teeth and other components of the masticatory organ to their physiologic limits (Shore, 1957). Heimlich (1960) realized that orthodontic treatment in itself equilibrates the teeth to a large degree, but that it also creates the need for further equilibration. When orthodontic treatment is completed, working surfaces have been brought into the path of occlusion which, because of restorations, wear, or non-wear in the previous environment, do not now function smoothly together, let alone in the harmony desired with other opposing teeth or the temporomandibular joints. It would seem that routine occlusal equilibration of completed orthodontic cases would be of value, if for no other reason than to establish the absence of prematurities (Blume, 1958).

Rothner (1952) and Roth (1973) also emphasize that occlusal adjustment is vital to orthodontic treatment. Equilibration of orthodontic cases should not be attempted until several years after retention, when it is clear that self-correction can not be expected (Sved, 1960, and

Frumker and Arnold, 1977). Heimlich (1960) likes to remove gross prematurities two to three months into retention. Williamson (1976) indicates that "settling in" will not solve functional deflections. More emphasis must be placed on the gnathological aspects of finished orthodontic cases (Chiappone, 1975).

Symptoms of temporomandibular joint dysfunction that may be related to occlusion may be divided into three principal categories: 1- history of joint sounds (either past or present), 2- limitation or deviation of mandibular movement, and 3- pain (Perry, 1973). Not too infrequently, either during the course of orthodontic treatment or sometime after appliance removal, the orthodontic patient may complain of clicking, subluxation, dislocation, and/or pain associated with the temporomandibular joints and masticatory muscles. Occlusal interferences are prime etiological factors (Roth, 1973). Evidence of some post-orthodontic patients developing temporomandibular joint problems have been shown by Thompson (1956), who describes his teenage retention and post-retention patients. Moyers (1955) demonstrated that forty percent of one hundred and fifty patients with temporomandibular joint disturbances, had previous orthodontic therapy.

Other investigations into the possible long term effects of orthodontic treatment have not always been favorable. Schluger (1968) notes that even with expertly

executed orthodontic treatment, there may be some penalty in longevity of teeth to be paid for orthodontic correction. We have come a long way to realize that Stutteville (1937) was in error when he said that injuries to the gingiva during orthodontic treatment will heal by "nature's kindness".

Sjolien and Zachrisson (1973) have shown that orthodontic treatment with fixed appliances results in a generalized reduction in the amount of bone support for the teeth, predominantly by apical blunting. It was slight, on the average, and may be considered to lie within an acceptable range to be compensated for by the achievement of good treatment results. Zachrisson (1974) measured significantly more alveolar bone loss in orthodontically treated patients than in untreated patients. There is a possibility that part of the differences between the two groups were present prior to, or otherwise unrelated to, treatment. Tirk (1967) also believes that unfavorable reactions of the investing tissues may occur more frequently than previously suspected.

Jekkals' (1970) sample of post-orthodontic patients revealed that seventeen out of eighteen patients had balancing side interferences and fourteen out of eighteen patients had a slide from centric relation to centric occlusion that was greater than one millimeter. Cohen (1965) showed in his investigation that seventy-five

percent of his treated group, and eighty-one percent of the untreated group had a slide from centric relation to centric occlusion. He also demonstrated premature contacts in approximately ninety percent of both groups.

METHODS AND MATERIALS

Two samples of patients were examined in this study. One consisted of forty patients who had undergone comprehensive orthodontic treatment at the orthodontic clinic at Case Western Reserve University, and were out of retention at least five years. The individuals in this group were gathered by responding to a telephone call requesting a follow-up examination. Out of two hundred such requests, forty-four were willing to come in for the examination. After a complete record check, four patients were deleted from the final sample because they did not fulfill the requirement of being out of retention at least five years. No attempt was made to see only ideally treated patients, but rather to see a random selection of post-orthodontically treated patients so that the bias in sampling could be reduced.

The second sample consisted of forty dental students who had not received any previous orthodontic treatment. The only other requirement was that they were within three years of the mean age of the treated patients. This sample will subsequently be referred to as the control group.

An examination was devised to be able to objectively categorize certain variables of both samples.

A data collection sheet was utilized for the examinations based on the works of Van Kirk (1959), Draker (1960), Proffit and Ackerman (1963), Granger (1967), Salzman (1968), Summers (1971), and Pickering (1975). A Total Index or Score was not used because the purpose was not to measure total malocclusion, as in epidemiological objectives or in treatment planning, but to measure the extent of certain characteristics in an individual.

Each patient was given the same examination, regardless of the group to which he belonged. The data collection sheet consisted of twenty-nine variables. A scoring key was employed to clearly define many of the categories, and to standardize their observation. The following is a list of the variables examined in this study.

1. Age
2. Sex
3. Race
4. Molar Classification

   By inspection in centric occlusion, each side was categorized into Angle's Class I, Class II, Class III, or, if the molars were end-to-end, into a fourth classification.

5. Missing Teeth

   This variable was divided into anterior and posterior components. The anterior section

consisted of any missing central or lateral incisors, cuspids, or first or second bicuspids. The posterior section consisted of any missing first, second, or third molars. One entry was designated for no missing teeth in each section.

6. Anterior Crowding in Maxillary and Mandibular Arches

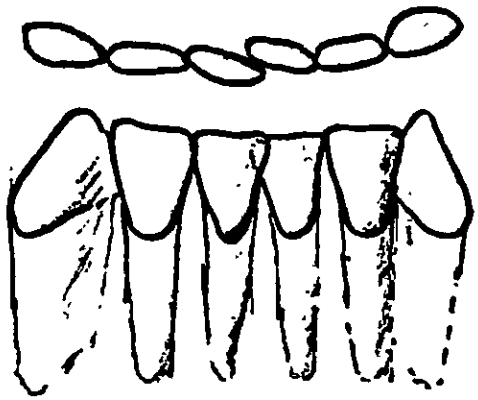
Anterior crowding (cuspid to cuspid) was categorized as follows: (see Fig. 1.)

1. None
2. Slight--when the total amount of overlap of the proximal surfaces of all six teeth did not exceed 2 mm
3. Moderate--when the total amount of overlap was greater that 2 mm , but did not exceed 4 mm
4. Severe--when the total amount of overlap was greater than 4 mm
5. Spaces--when there was no overlap of teeth and spaces were evident between any or all of the incisors, mesial to the cuspids

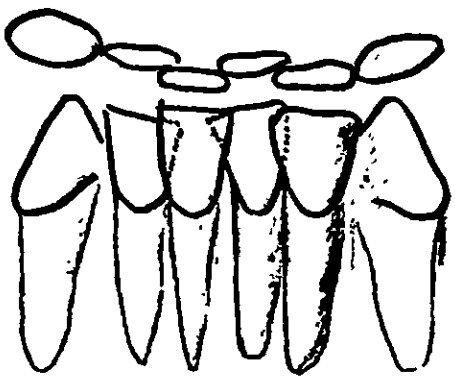
7. Crossbite

Crossbites were noted according to the tooth

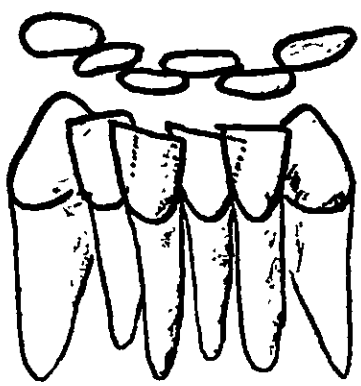
Fig. 1. Anterior Crowding



Slight-≤ 2 mm



Moderate->2<4 mm



Severe-≥ 4 mm

or groups of teeth involved, as discrepancies from normal positions.

8. Intercuspation

This was examined on each side by observing the buccal segments (cuspid to second molar) at a 90 degree angle while the patient was in centric occlusion. Intercuspation was divided into the following categories:

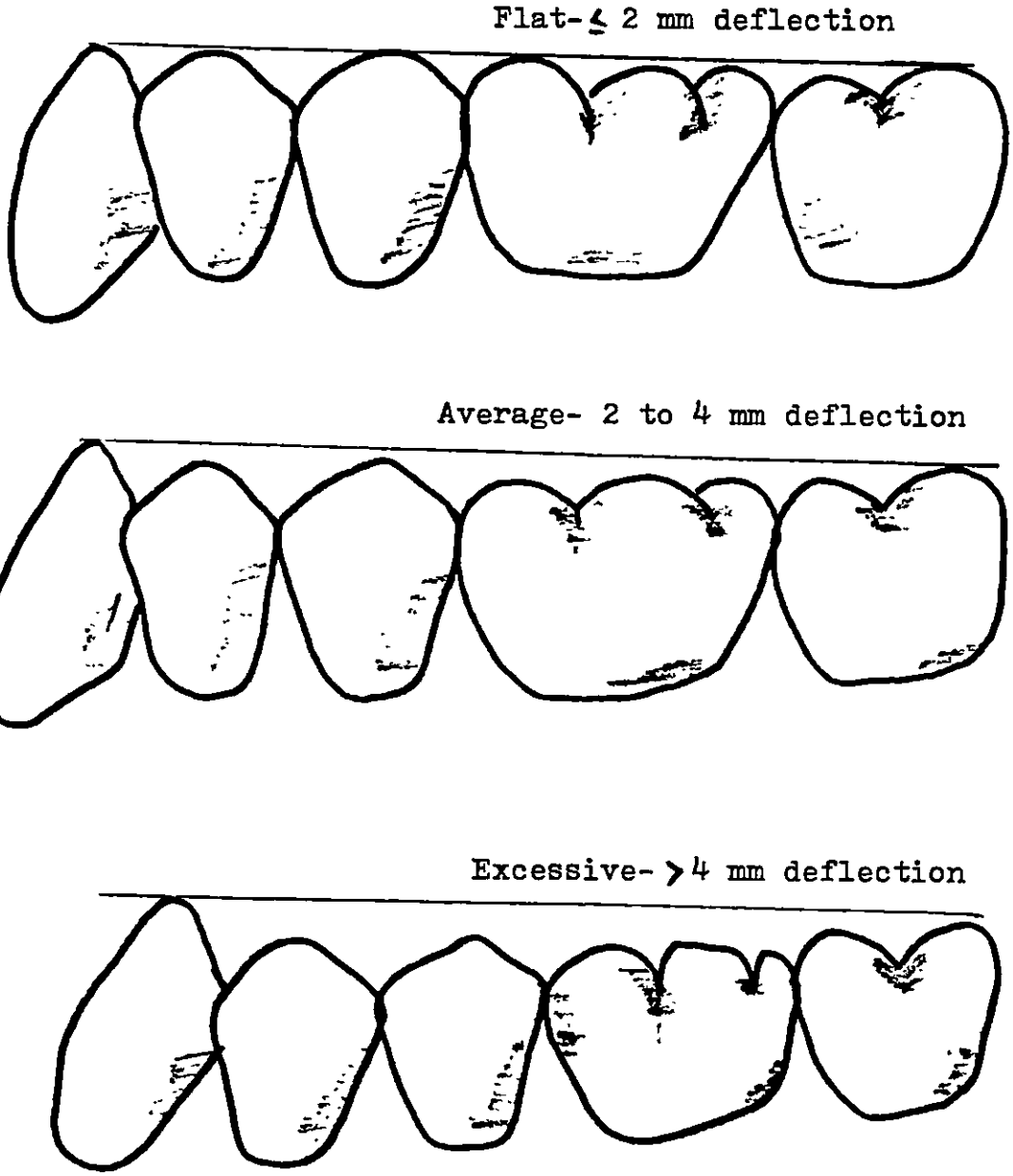
1. Good--all of the teeth had to have proper and complete cusp-fossa relationships
2. Fair--when one or two teeth did not meet the requirements of proper interdigitation
3. Poor--when more than two teeth were not in correct position

9. Curve of Spee

This category was divided into three groups, depending on the amount of curve deflection to a straight line from the incisal edge of the lower central incisors to the distal of the lower second molars. (see Fig. 2.)

1. Flat--with less than 2 mm deflection
2. Average--2 to 4 mm deflection
3. Excessive--over 4 mm deflection

Fig. 2. Curve of Spee



10. Overbite

The amount of vertical overlap of the maxillary central incisors to the mandibular central incisors as measured in millimeters.

11. Overjet

The amount of horizontal overlap of the maxillary central incisors to the mandibular central incisors as measured in millimeters.

12. Mid-lines Coinciding

Recorded as coinciding or not.

13. Anterior Open Bite

Recorded as present or not.

14. Open Contact on the Distal of Cuspids

A contact was considered open when the measuring instrument (the thickness of a Trubyte ruler) passed through the contact area to the gingiva. O'Leary (1975) describes another method to evaluate contacts by resistance with dental floss, which can be subjective. The ruler was utilized to provide a standard measurement and to avoid confusion in defining what was considered an open contact.

15. Wear Facets on Cuspids

Facets were noted as flat, shiny spots on

the mesial and/or distal inclines or the cusp tips, and were recorded as present or not.

16. Wear Facets on Other Teeth

This variable used the same criteria as for cuspids, but for any other teeth.

17. Previous Equilibration

The patient was asked if he had previously had his teeth "ground on" or adjusted other than for restorative procedures, to determine if an occlusal equilibration had been performed.

18. Lateral Excursive Function

The type of lateral excursive function was examined to determine the functional occlusion scheme present for each patient. The individual was told to close his teeth together, and to slide his mandible to each side until the cuspids were end-to-end. The following types of disclusion were noted:

1. Cuspid Protection Occlusion
2. Group Function Occlusion
3. Other (usually somewhere in-between)

19. Centric Relation-Centric Occlusion Slide

Each patient was requested to relax while his mandible was positioned into centric relation in a manner demonstrated by

Ingervall (1971, 1976) and Williams (1971). He was then told to lightly close together until the first contact was felt, and then to hold still. While observing the cuspids and incisors, he was told to squeeze his teeth all the way together. It was quite easy to reproduce this movement several times for each patient, and to decide if there was a slide into centric occlusion. This variable was divided into the following:

1. No slide
2. A slide of 1 mm or less
3. A slide of more than 1 mm

20. Protrusive Interferences

This was observed by having the patient begin in centric occlusion and then sliding his mandible forward until the incisors were end-to-end. Any interfering tooth that altered a smooth slide was recorded as an interference.

21. Non-working Interferences

For this excursion, the patient was told to close in centric occlusion with a strip of Madame Butterfly Articulating Ribbon between his teeth. The patient then moved his man-

dible toward the working side without separating his teeth. He was told to stop when he had moved out of centric occlusion approximately two millimeters. While still holding this position, an attempt was made to remove the ribbon. If with moderate pressure, the ribbon could not be dislodged, then a non-working interference was noted. The offending cusp or cusps could be seen by inspection. This technique is described by Frumker and Arnold (1976).

22. Temporomandibular Joint Symptoms

Each patient was asked if he had previously, or at the time of the examination, had any of the following:

1. No symptoms
2. Pain
3. Clicking or popping sounds
4. Both of the above
5. Headaches or tooth discomfort

23. History of Clenching, Bruxing, or Grinding

This was recorded as present or not.

24. Muco-gingival Problems

The amount of attached gingiva was examined

on the labial aspect of the mandibular central and lateral incisors, and cuspids. A muco-gingival problem was defined as less than one millimeter of attached gingival tissue evident above the alveolar mucosa on one or more of these teeth. The patient was informed of the findings, and that this should be reported to his dentist for treatment. (see Fig. 3)

Statistical Methods

Observations were subjected to statistical analysis by the use of an SPSS (Statistical Package for the Social Sciences) program. All measurements and observations were made by the same examiner. The entries were coded on key punch cards, which were verified for use in analysis by computer. An example of the coding process follows:

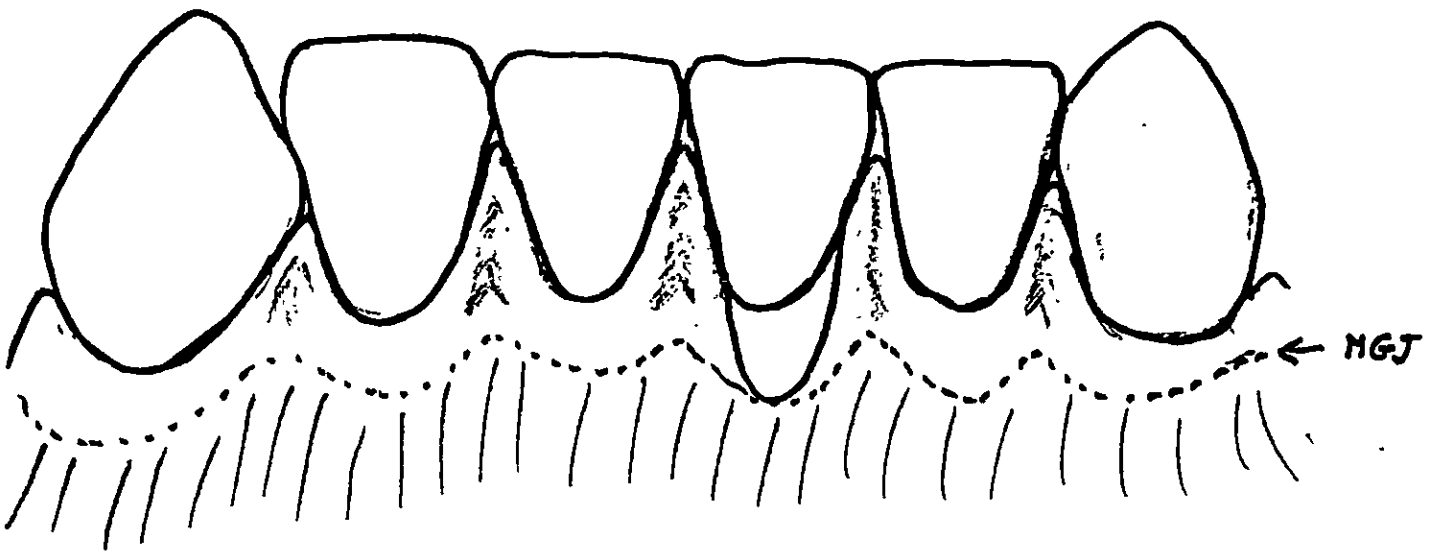
1. For variables using the ordinal scale
   (eg.V-11, Intercuspation)

Good	(coded)	1
Fair		2
Poor		3

2. For variables using the nominal scale
   (eg.V-12, Curve of Spee)

Flat	-1
Average	0
Severe	+1

Fig. 3. Muco-gingival Problems



MGJ= muco-gingival junction

The subsequent list is a brief description of the analysis used in this study.

1. Descriptive Analysis- encompasses raw data indicated by numbers and percentages for each variable in both groups.
2. Univariate F Ratios- are one way analyses of variance tests for equality of group means on a single discriminating variable, calculated for each variable.
3. Pearson's Correlation Coefficients- are obtained for all variables in each group to determine which ones are significantly related to each other. The coefficient and significance level for each relationship is available for examination.
4. Multiple Stepwise Regression Analysis- is a technique used to determine which of the independent variables is actually predicting, or accounting for, the majority of the variance in the dependent variable. This program computes a sequence of multiple linear regression equations in a stepwise manner. At each step, one variable is added to the regression equation. This variable has the highest partial correlation with

the dependent variable partialled on the variables which have already been added. This is also the variable which, if added, would have the highest F value.

5. Discriminant Analysis- begins with the desire to statistically distinguish between two or more groups of cases. To distinguish between the groups, the researcher selects a collection of discriminating variables that measure characteristics on which the groups are expected to differ. The mathematical objective of discriminant analysis is to weight and linearly combine the discriminating variables in some fashion so that the groups are forced to be as statistically distinct as possible. In other words, the objective is to be able to tell two or more groups apart. The statistical theory of discriminant analysis assumes that the discriminating variables have a multivariate normal distribution and that they have equal variance-covariance matrices within each group. Weighting coefficients can be interpreted much as in multiple regression. In this respect, they serve to identify the variables which contribute

most to differentiation along the respective dimension. As a check of the adequacy of the discriminant functions, the original set of cases can be classified to see how many are correctly classified by the variables being used. In the stepwise selection method, independent variables will be selected for entry into the analysis on the basis of their discriminating power. The procedure begins by selecting the single best-discriminating variable according to a user-determined criterion. A second discriminating variable is selected as the variable best able to improve the value of the discrimination criterion in combination with the first variable. The third and subsequent variables are similarly selected according to their ability to contribute to further discrimination. At each step, variables already selected may be removed if they are found to reduce discrimination when combined with more recently selected variables. This occurs because the information that they contain about group differences is now available in some combination of the other included var-

iables. A variable which has been removed at one step may re-enter at a later step if it satisfies the selection criterion at that time. The criterion to be used in the stepwise selection is indicated by the method selected. The methods specified in this study are the following:

1. Minimum Wilks' Lambda- the criterion is the multivariate F ratio for the test of differences among the groups. The variable which maximixes the F ratio also minimizes Wilks' lambda, a measure of group discrimination focusing on variance.
2. Maximum Mahalanobis Distance- the criterion seeks to maximize the Mahalanobis distance between the two closest groups. The measure of group discrimination in this method focuses on the differences between group means.

The results of the two methods were examined to see if they produced different conclusions.

RESULTS

Descriptive Statistics

Observations were recorded for each variable on a data collection sheet. Variables for age, overbite, and overjet were tabulated with the appropriate statistics as indicated in Table 1. The relative number and corresponding percentage of incidence for all other variables in both samples is presented in Table 2. Most variables are broken down into sub-categories to obtain as much information on each item as possible. The complete list of standard deviations for each variable is reported in the Appendix in Table 9.

Univariate F Tests

The variables which yielded a significant F value, at $p<.05$ and $p<.01$ (1,78 df), are indicated in Table 3. The following is a list of all variables and their corresponding numbers:

V-1 Patient's age

V-2 Sex

V-3 Race

V-4 Molar classification, right side

V-5 Molar classification, left side

V-6 Missing anterior teeth

V-7 Missing posterior teeth

V-8 Anterior crowding in the maxillary arch

V-9 Anterior crowding in the mandibular arch

V-10 Crossbite

V-11 Intercuspation

V-12 Curve of Spee

V-13 Overbite

V-14 Overjet

V-15 Mid-lines coincide

V-16 Anterior open bite

V-17 Open contact on the distal of cuspids

V-18 Wear facets on cuspids

V-19 Wear facets on other teeth

V-20 Previous equilibration

V-21 Lateral excursive function, right side

V-22 Lateral excursive function, left side

V-23 Centric relation-centric occlusion slide

V-24 Protrusive interferences

V-25 Non-working interferences

V-26 Temporomandibular joint symptoms

V-27 History of bruxing, clenching, or grinding

V-28 Muco-gingival problems

V-29 Orthodontically treated

TABLE 1

VARIABLES WITH DISCRETE QUANTITATIVE STATISTICS

Variable	Mean	Median	Mode	Maximum	Standard Deviation
Age (in years)					
Treated	22.7	22.6	23.0	27.0	2.0
Control	23.3	23.3	24.0	27.0	1.2
Overbite (in mm)					
Treated	3.5	3.7	3.0	6.0	1.6
Control	2.7	2.8	3.0	6.0	1.5
Overjet (in mm)					
Treated	3.2	3.1	3.0	6.0	1.3
Control	2.6	2.4	2.0	6.0	1.4

TABLE 2

DATA FOR TREATED AND CONTROL SAMPLES

Variable	Treated		Control	
	Incidence	Percent	Incidence	Percent
Sex				
Male	14	35.0	33	82.5
Female	26	65.0	7	17.5
Total	40	100.0	40	100.0
Race				
Black	4	10.0	0	-
White	36	90.0	39	97.5
Other	0	-	1	2.5
Total	40	100.0	40	100.0
Molar Classification (Right side)				
Class I	29	72.5	29	72.5
Class II	0	-	4	10.0
Class III	1	2.5	3	7.5
End-to-End	10	25.0	4	10.0
Total	40	100.0	40	100.0
Molar Classification (Left side)				
Class I	28	70.0	28	70.0
Class II	1	2.5	3	7.5
Class III	1	2.5	3	7.5
End-to-End	10	25.0	6	15.0
Total	40	100.0	40	100.0

TABLE 2 continued

Variable	Treated		Control	
	Incidence	Percent	Incidence	Percent
Missing Anterior Teeth				
None	9	22.5	39	97.5
4 first bicuspids	29	72.5	0	-
Other	2	5.0	1	2.5
Total	40	100.0	40	100.0
Missing Posterior Teeth				
None	18	45.0	20	50.0
4 third molars	12	30.0	9	22.5
2 maxillary third molars	3	7.5	1	2.5
2 mandibular third molars	1	2.5	2	5.0
4 first molars	1	2.5	2	5.0
Other	5	12.5	6	15.0
Total	40	100.0	40	100.0
Anterior Crowding (Maxillary arch)				
None	14	35.0	9	22.5
Slight	17	42.5	16	40.0
Moderate	1	2.5	5	12.5
Severe	0	-	2	5.0
Spaces	8	20.0	8	20.0
Total	40	100.0	40	100.0

TABLE 2 continued

Variable	Treated		Control	
	Incidence	Percent	Incidence	Percent
Anterior Crowding (Mandibular arch)				
None	11	27.5	6	15.0
Slight	18	45.0	16	40.0
Moderate	8	20.0	7	17.5
Severe	1	2.5	5	12.5
Spaces	2	5.0	6	15.0
Total	40	100.0	40	100.0
Crossbites				
None	30	75.0	25	62.5
Third molars	3	7.5	0	-
Second molars	5	12.5	8	20.0
First molars	0	-	1	2.5
Bicuspids	1	2.5	3	7.5
Cuspids	0	-	2	5.0
Other	1	2.5	1	2.5
Total	40	100.0	40	100.0
Intercuspation				
Good	10	25.0	12	30.0
Fair	14	35.0	13	32.5
Poor	16	40.0	15	37.5
Total	40	100.0	40	100.0
Curve of Spee				
Flat	10	25.0	14	35.0
Average	30	75.0	25	62.5
Severe	0	-	1	2.5
Total	40	100.0	40	100.0

TABLE 2 continued

Variable	Treated		Control	
	Incidence	Percent	Incidence	Percent
Overbite (mm)				
0	3	7.5	5	12.5
1	0	-	2	5.0
2	8	20.0	9	22.5
3	7	17.5	13	32.5
4	11	27.5	8	20.0
5	7	17.5	1	2.5
6	4	10.0	2	5.0
Total	40	100.0	40	100.0
Overjet (mm)				
0	1	2.5	1	2.5
1	2	5.0	7	17.5
2	6	15.0	13	32.5
3	19	47.5	11	27.5
4	5	12.5	4	10.0
5	5	12.5	2	5.0
6	2	5.0	2	5.0
Total	40	100.0	40	100.0
Mid-lines Coinciding				
Yes	23	57.5	16	40.0
No	17	42.5	24	60.0
Total	40	100.0	40	100.0
Anterior Open Bite				
Present	3	7.5	3	7.5
Not Present	37	92.5	37	92.5
Total	40	100.0	40	100.0

Table 2 continued

Variable	Treated		Control	
	Incidence	Percent	Incidence	Percent
Open Cuspid Contacts				
None	30	75.0	32	80.0
1 open contact	4	10.0	2	5.0
2 open contacts	3	7.5	4	10.0
3 open contacts	2	5.0	1	2.5
4 open contacts	1	2.5	1	2.5
Total	40	100.0	40	100.0
Wear Facets on Cuspids				
Present	27	67.5	34	85.0
Not Present	13	32.5	6	15.0
Total	40	100.0	40	100.0
Wear Facets on Other Teeth				
Present	24	60.0	33	82.5
Not Present	16	40.0	7	17.5
Total	40	100.0	40	100.0
Previous Equilibration				
Yes	9	22.5	4	10.0
No	31	77.5	36	90.0
Total	40	100.0	40	100.0
Lateral Excursive Function (Right side)				
Cuspid protection	29	72.5	19	47.5
Group function	6	15.0	18	45.0
Other	5	12.5	3	7.5
Total	40	100.0	40	100.0

TABLE 2 continued

Variable	Treated		Control	
	Incidence	Percent	Incidence	Percent
Lateral Excursive Function (Left side)				
Cuspid Protection	26	65.0	17	42.5
Group function	10	25.0	20	50.0
Other	4	10.0	3	7.5
Total	40	100.0	40	100.0
Centric Relation-Centric Occlusion Slide				
None	7	17.5	2	5.0
Less than 1 mm	12	30.0	17	42.5
Greater than 1 mm	21	52.5	21	52.5
Total	40	100.0	40	100.0
Protrusive Interferences				
None	34	85.0	25	62.5
Molars	2	5.0	3	7.5
Bicuspids	0	-	4	10.0
Cuspids	3	7.5	7	17.5
Incisors	1	2.5	1	2.5
Total	40	100.0	40	100.0
Non-working Interferences				
None	10	25.0	11	27.5
First molars	1	2.5	1	2.5
Second molars	24	60.0	24	60.0
Third molars	1	2.5	2	5.0

TABLE 2 continued

Variable	Treated		Control	
	Incidence	Percent	Incidence	Percent
All molars	4	10.0	2	5.0
Total	40	100.0	40	100.0
Temporomandibular Joint Symptoms				
None	25	62.5	32	80.0
Pain	1	2.5	0	-
Popping or clicking	12	30.0	6	15.0
Both the above	2	5.0	2	5.0
Total	40	100.0	40	100.0
Bruxing, Clenching or Grinding History				
Yes	12	30.0	24	60.0
No	28	70.0	16	40.0
Total	40	100.0	40	100.0
Muco-gingival Problems				
Yes	17	42.5	5	12.5
No	23	57.5	35	87.5
Total	40	100.0	40	100.0
Orthodontically Treated				
Yes	40	100.0	0	-
No	0	-	40	100.0
Total	40	100.0	40	100.0

TABLE 3

SIGNIFICANT UNIVARIATE F TESTS

$p < .01$ ($F_{1,78} = 6.99$)

Variable	Name	F Value
V-6	Missing anterior teeth	110.38
V-2	Sex	23.66
V-28	Muco-gingival problems	9.92
V-27	Bruxing history	7.80

$p < .05$ ($F_{1,78} = 3.97$)

V-24	Protrusive interferences	5.46
V-21	L. E. F. on right side	5.43
V-13	Overbite	5.30
V-19	Wear facets on other teeth	5.14
V-22	L. E. F. on left side	4.18
V-8	Anterior crowding in Maxilla	4.08
V-14	Overjet	4.07

Pearson's Correlation Coefficients

The Pearson's correlation coefficient analysis produced statistically significant pairs of variables for $p \leq .05$. A list of these paired variables at $p \leq .01$ is presented in Table 4. The entire analysis is reported in the Appendix in Table 10.

Multiple Stepwise Regression Analysis

In this study, it was assumed that the variables for sex, V-2, and anterior missing teeth, V-6, would bias the samples. The great preponderance of missing bicuspids would presumably classify the patient into the orthodontically treated sample. The patient's sex would also bias the statistical analysis due to the relatively few number of females in the control group. These two variables could account for a disproportionate amount of the regression. Table 5 illustrates the effect that V-2 and V-6 have on the regression analysis. The dependent variable is V-29, orthodontic treatment. It should be noted that the combination of variables reported in Table 5 accounts for 64.9% of the regression, but V-6 alone accounts for 58.6%.

The regression analysis without variables V-2 and V-6 is presented in Table 6. This is a more significant

TABLE 4

PEARSON'S CORRELATION COEFFICIENT ANALYSIS
FOR $p \leq .01$

Treated Group n= 40			Control Group n= 40		
Variables	Coefficient	Significance	Variables	Coefficient	Significance
1 and 7	.3710	.009	1 and 23	-.4065	.005
1 and 11	.4277	.003	4 and 8	.4173	.004
2 and 5	.3456	.014	4 and 11	.5506	.001 *
2 and 7	.3898	.006	5 and 10	.3664	.010
2 and 28	-.4188	.004	5 and 11	.6463	.001 *
4 and 5	.4493	.002	5 and 15	.3586	.012
4 and 11	.6143	.001 *	8 and 11	.3978	.006
5 and 11	.6461	.001 *	8 and 17	-.5615	.001 *
8 and 9	.4050	.005	12 and 21	-.4171	.004
8 and 17	-.4120	.004 *	13 and 16	.5172	.001 *
9 and 17	-.4472	.002	13 and 24	-.5037	.001 *
13 and 16	.5103	.001 *	15 and 19	-.4298	.003
13 and 24	-.6642	.001 *	19 and 24	-.3568	.012
16 and 24	-.4120	.004	20 and 25	.3546	.012
18 and 19	.7409	.001	21 and 22	.6800	.001 *
18 and 26	.3445	.014	21 and 28	-.4029	.005
21 and 22	.4254	.003 *	23 and 27	-.3474	.014
			23 and 28	-.3595	.011

* denotes pairs of significant variables appearing in both groups

TABLE 5

MULTIPLE STEPWISE REGRESSION ANALYSIS

WITH V-2 AND V-6

Variable	R^2
V-6	.58594
V-2	.60838
V-8	.62645
V-27	.63849
V-19	.64863

(R^2= relative fraction of the total)

TABLE 6

MULTIPLE STEPWISE REGRESSION ANALYSIS

WITHOUT V-2 AND V-6

Variable	R^2
V-28	.11285
V-21	.23212
V-27	.33553
V-26	.37025
V-15	.40689

(R^2= relative fraction of the total)

analysis, since this combination of variables accounts for 40.7% of the regression, without any one being over-influential.

Discriminant Analysis

The summation of the discrimant analysis using the minimum Wilks' lambda criterion is reported in Table 7. Table 8 indicates the results using the Mahalanobis distance criterion. Both of these tables are presented without variables V-2 and V-6, which produced the same effect as in multiple regression analysis.

TABLE 7

DISCRIMINANT ANALYSIS USING THE MINIMUM WILKS' LAMBDA METHOD

Step Number	Variable Entered	Wilks' Lambda
1	V-28	.88715
2	V-21	.76788
3	V-27	.66447
4	V-26	.62975
5	V-15	.59311

Eigenvalue= .79790
Canonical Correlation= .666
Final Wilks' Lambda= .59311

Prediction Results-

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
Group 1	40	30 (75.0%)	10 (25.0%)
Group 2	40	7 (17.5%)	33 (82.5%)

Percentage of 'grouped' cases correctly classified= 78.75%

TABLE 8

DISCRIMINANT ANALYSIS USING THE GENERALIZED MAHALANOBIS DISTANCE METHOD

Step Number	Variable Entered	Wilks' Lambda
1	V-28	.88715
2	V-27	.76908
3	V-21	.69236
4	V-26	.65437
5	V-15	.61971

Eigenvalue=.73012
Canonical Correlation= .650
Final Wilks' Lambda= .61971

Prediction Results-

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
Group 1	40	31 (77.5%)	9 (22.5%)
Group 2	40	8 (20.0%)	32 (80.0%)

Percentage of 'grouped' cases correctly classified= 78.75%

DISCUSSION

The descriptive analysis of all the variables may be closely examined in the section on Results. There is no significant difference between the mean age of each group, or for the number of patients composing each sample; therefore, the two groups may be considered comparable. The number of male and female individuals in each group are not equal, but Van Kirk and Pennell (1959), and Ingervall (1968) have demonstrated that there is little evidence to suggest that there is any sex difference in patient response. Consequently, variable V-2 is not analyzed for differences in results.

It is interesting to note how similar the two samples are in several respects. There is exactly the same number of Class I molar relationships on the right side (72.5%), and left side (70.0%), anterior open bites (7.5%), centric relation slides of 1mm or less (47.5%), and non-working interferences on second molars (60.0%) in both groups. Variables for posterior missing teeth, open contacts, and intercuspation are within 5.0% of being exactly the same in both groups.

The variable with the greatest variance between the two samples, and subsequent largest F value, is V-6, the absence of bicuspids. This is an expected phenomena

since approximately 80.0% of all orthodontically treated patients at Case Western Reserve University are bicuspid extraction cases.

The data supports two other conclusions that are to be anticipated and are statistically significant at $p \leq .05$. The orthodontically treated sample had less anterior crowding and protrusive interferences than the untreated sample.

The results of several variables prove to be unexpected in an orthodontically treated sample. These include the high incidence (42.5%) of muco-gingival problems in the treated group as compared to the control group (12.5%). There is also statistically more overbite and overjet in the treated group. (See tables 1 and 3.)

The orthodontically treated sample displays significantly ($p < .01$) more muco-gingival problems in the mandibular incisor area than the control group. Possible explanations for this might be an excessive amount of labial root torque during treatment, or a post-treatment growth spurt of the mandible which could upright the mandibular incisors even more than during treatment, causing their roots to exert pressure against the thin labial plate of bone and attached gingiva in the mandibular incisor region (Andrews, 1972). This phenomena is similarly described by Rose (1967) as an occlusal dis-

harmony which occurs where upper anteriors do not adequately enclose lower crowded incisors. Proximal enamel recontouring could affect the interdental papilla, which in turn could contribute to some gingival recession. Pearson (1968), who measured gingival recession rather than the amount of attached gingiva present, noted that significantly more recession was demonstrated in his orthodontically treated sample. A more probable explanation may be given for the disparity between the two groups if an initial examination revealed a muco-gingival problem when the patient first presented for treatment. Finally, perhaps aligning mandibular anterior teeth actually does predispose a patient to early loss of attached gingiva.

The fact that statistically more overbite and overjet is evident in the orthodontically treated sample must be reviewed. The amount of overbite and overjet which each patient exhibited before treatment is not being analyzed. The treated patients conceivably had a much worse condition before treatment, and the final result is a great improvement.

There were no patients with a severe or handicapping malocclusion in the control group. Presumably, any patient with a severe problem would have undergone orthodontic therapy. Therefore, the control group is not exactly identical to the treated group, and some of the

comparisons and findings need to be taken into consideration. A true comparison would have to be between untreated patients who have the same malocclusions as the patients did before receiving orthodontic treatment. It must be emphasized that the purpose in the selection of the control group was not to observe ideal occlusions, but to compare treated patients to a chronologically equivalent group of untreated people.

As already mentioned, this study was designed to be as objective as possible. In previous studies to evaluate post-orthodontically treated patients, samples were biased in selecting only certain cases to be included. Cohen (1965) used only patients whom he considered to possess ideal occlusions. Pritchard (1975) selected patients who were undergoing periodontal therapy. Ahlgren and Posselt (1963) had a study with a mean age of only eleven years old in their untreated sample, which is too young for the patients to have erupted second molars. Clinical investigations must make every effort to reduce any prejudice in the methods employed while making comparisons.

The fact that more patients in the control group admitted to bruxing their teeth may be attributed to using sophomore dental students as a sample population. They are under a considerable amount of stress and might relieve their tension through bruxing. Therefore, the

control group may exhibit a higher incidence of bruxing than in the normal population. It must also be noted that the dental students may have had their own reasons for participating in the examination. Perhaps these students, like the treated patients, were individuals who underwent the examination to learn if they had a problem, or to discuss a problem that they believed they had.

A flat curve of Spee is more evident in the control group. If the orthodontically treated group had an excessive curve before treatment, and was leveled during treatment, then the possibility of some relapse to an average amount of curve after treatment exists. Huffer et al. (1972) explains that a flat occlusal plane is essential to non-interfering occlusion. Most orthodontists treat with a goal of a flat curve of Spee in mind. Andrews (1972) believes that intercuspation of the teeth is best when the plane of occlusion is relatively flat. His work also corroborates that there is a normal tendency for the curve of Spee to deepen in time.

The control group exhibits a much higher incidence (45.0%) of patients with "group function occlusion" than the treated group (15.0%). However, "canine protected occlusion" was the most common for both groups. This is in conflict with Ingervall (1976) who found "group function occlusion" to be the most common.

Analysis via Pearson's correlation coefficients was employed to examine all possible pairs of variables for significant relationships. As anticipated, variables for molar classification and intercuspation have a statistically significant interrelation ($p=.001$). Crowding in the maxillary arch is significantly related ($p=.005$) to crowding in the mandibular arch. An interesting finding in the treated sample is the relationship between wear facets on cuspids and temporomandibular joint symptoms ($p=.014$). This supports the hypothesis that wear facets on cuspids are a sign that the patient has some interferences causing him to brux, and that an equilibration should be performed to remove the prematurities. The control group exhibited a significant relationship ($p=.014$) between the patient's bruxing symptoms and a slide from centric relation to centric occlusion. A slide is probably the result of centric interferences, which should also be removed. Roth (1977) advises that repositioning splints should be worn by each patient before measuring the amount of slide present. This would remove the inhibitions and muscle ingrams usually present which make a true centric relation record difficult to obtain.

Certain pairs of variables prove to be statistically significant in both samples. All six pairs are consistent with orthodontic reasoning today. (See table 4.)

The multiple regression analysis produced a list of independent variables which account for the majority of the variance in the dependent variable, V-29, orthodontic treatment. Since the analysis is performed in a stepwise manner, the amount of regression accounted for can be distinguished for each variable. (See table 6.)

Discriminant analysis selects the "best" set of discriminating variables. The results produced are very similar to the multiple regression analysis method, which is to be expected. However, in this analysis, the dependent variable is not known. It is interesting to note that the Wilks' lambda criterion produced a final list of variables which is identical to that of the multiple regression analysis. The analysis using the generalized Mahalanobis distance criterion is similar, except for the order of the second and third variables (see tables 6, 7, and 8). The Wilks' lambda criterion produced a higher degree of separation, as indicated by the initial and final Wilks' lambda values. The larger lambda is, the less information remaining. Two other statistics, the eigenvalue (a measure of the relative importance of the function) and the canonical correlation (the correlation ratio--a measure of the function's ability to discriminate among the groups) indicate that the Wilks' lambda

criterion is more significant than the Mahalanobis distance criterion in analyzing discriminant functions.

Besides discriminant analysis being beneficial in analytic use, it is also a powerful classification technique (Nie et al., 1975). The five variables enumerated by analysis, in combination with one another, best differentiate among the patients in the two groups. Variables for lateral excursive function, bruxing history, TMJ symptoms, midlines coinciding, and muco-gingival problems are capable of discriminating among the patients. Utilizing these results in a logical sequence would enable a patient to be classified into either the treated or untreated group. The data indicates that 78.75% of the patients were correctly classified in their respective samples.

SUMMARY AND CONCLUSIONS

Orthodontists are becoming increasingly more aware that proper functional occlusion is an integral part of treatment. Interferences which a patient may exhibit at the end of orthodontic therapy are a potential cause for severe complications in his later life. The patient should not be dismissed until the stability of the dentition and the health of the supporting structures can be assured.

This investigation was performed to assess the static and functional occlusal status of post-orthodontically treated patients. Forty patients, who had received orthodontic treatment at Case Western Reserve University and were out of retention at least five years, were examined. Forty additional patients, who had not received any orthodontic treatment and were to serve as a control group, were similarly examined. Twenty-eight variables were observed in each patient, and noted according to a method adapted from existing indices.

Relationships were established between the two samples and within each one. A series of analyses, including univariate F tests and correlation coefficients, were performed to indicate which variables were statistically

significant. Another series of analyses, including multiple regression and discriminant functions, were performed to indicate which combination of variables best discriminated among the samples.

The results of the study may be summarized:

1. There was statistically more overbite, overjet, and muco-gingival problems in the orthodontically treated sample than in the control group.

2. There was statistically more bruxing, protrusive interferences, wear facets on teeth, and anterior crowding in the maxillary arch in the control group than in the treated group.

3. 40% of the orthodontically treated patients and 37.5% of the control group had poor intercuspation.

4. "Group function occlusion" was demonstrated in 50% of the control group, and only in 25% of the treated group.

5. A slide from centric relation to centric occlusion of 1 mm or less was evident in 47.5% of each sample.

6. Approximately 75% of the patients had non-working interferences; however, 60% of the interferences involved second molars in both groups.

7. TMJ symptoms were more prevalent in the orthodontically treated group (37.5%) than in the control group (20%).

8. The amount of anterior crowding in the maxillary arch was significantly related to the amount of anterior crowding in the mandibular arch.

9. Variables for overbite and protrusive interferences were significantly related.

10. Variables for wear facets on cuspids and TMJ symptoms were significantly related in the treated group.

11. Variables for a centric relation slide and a bruxing history were significantly related in the control group.

12. Variables for lateral excursive function, bruxing history, TMJ symptoms, mid-lines coinciding, and muco-gingival problems, in combination with one another, were capable of best discriminating the patients into the two groups.

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APPENDIX

TABLE 9

STANDARD DEVIATIONS FOR EACH VARIABLE

Variable Number	Name	Standard Deviations	
		Treated	Control
V-1	Age	2.00	1.22
V-2	Sex	.48	.38
V-3	Race	.30	.16
V-4	Molar class., right	.88	.67
V-5	Molar Class., left	.88	.75
V-6	Missing anterior teeth	.42	.16
V-7	Missing post. teeth	.50	.51
V-8	Ant. crowding, max.	.82	1.10
V-9	Ant. crowding, mand.	.88	1.17
V-10	Crossbite	.44	.49
V-11	Intercuspation	.80	.83
V-12	Curve of Spee	.44	.53
V-13	Overbite	1.60	1.51
V-14	Overjet	1.28	1.37
V-15	Mid-lines coincide	.50	.50
V-16	Anterior open bite	.27	.27
V-17	Open cuspid contact	.44	.41
V-18	Wear facets, cuspids	.47	.36
V-19	Wear facets, others	.50	.38
V-20	Previous equilibration	.42	.30
V-21	L.E.F., right	.75	.97
V-22	L.E.F., left	.87	.97
V-23	CR-CO slide	.51	.51
V-24	Protrusive interfer.	.36	.49
V-25	Non-working interfer.	.44	.45
V-26	TMJ symptoms	.49	.41
V-27	Bruxing history	.46	.50
V-28	Muco-gingival problems	.50	.35

TABLE 10

PAIRS OF VARIABLES WITH SIGNIFICANT PEARSON'S CORRELATION COEFFICIENTS

($p \leq .05$)

Treated		Control	
Variables	p value	Variables	p value
1 and 6	.03	1 and 14	.03
1 and 7	.009	1 and 23	.005
1 and 11	.003	1 and 28	.04
1 and 20	.05	3 and 17	.02
3 and 23	.02	4 and 5	.02
3 and 26	.05	4 and 8	.004
4 and 5	.002	4 and 11	.001
4 and 11	.001	4 and 16	.05
4 and 14	.03	4 and 21	.03
4 and 19	.02	4 and 22	.02
5 and 11	.001	5 and 10	.01
5 and 16	.05	5 and 11	.001
8 and 9	.005	5 and 15	.01
8 and 17	.004	5 and 16	.02
8 and 28	.03	5 and 18	.02
9 and 17	.002	5 and 19	.04
9 and 25	.04	5 and 27	.05
9 and 28	.02	7 and 9	.04
10 and 20	.02	8 and 9	.02
10 and 26	.02	8 and 11	.006
11 and 14	.05	8 and 16	.04
12 and 17	.02	8 and 17	.001
12 and 21	.03	8 and 21	.02
12 and 22	.02	8 and 28	.04
13 and 16	.001	9 and 17	.02
14 and 24	.04	10 and 11	.03
16 and 24	.004	10 and 23	.03
17 and 23	.02	10 and 28	.03
18 and 19	.001	11 and 15	.05
18 and 26	.01	12 and 13	.03
19 and 26	.02	12 and 19	.04
20 and 21	.03	12 and 20	.04
21 and 22	.003	12 and 21	.004
21 and 25	.02	13 and 16	.001
22 and 24	.04	13 and 21	.05
22 and 25	.02	13 and 24	.001
25 and 26	.02	14 and 16	.03

TABLE 10 continued

Treated		Control	
Variables	p value	Variables	p value
25 and 28	.05	14 and 24	.03
26 and 27	.04	14 and 28	.04
27 and 28	.02	15 and 19	.003
		15 and 20	.04
		17 and 21	.02
		18 and 25	.05
		18 and 28	.05
		19 and 24	.01
		20 and 22	.02
		20 and 25	.01
		21 and 22	.001
		21 and 24	.03
		21 and 28	.005
		23 and 27	.01
		23 and 28	.01
		26 and 27	.04

(43) _____ Edge

(42) _____ Arch

(41) _____ Edge

TABLE 11

DATA COLLECTION SHEET

Patient's Name_____(1-7)
Age_____(8-9)
Sex_____(10)
Race_____(11)
Molar Classification: Right Side_____(12) Left Side_____(13)
Missing Teeth, Anterior_____(14)
Missing Teeth, Posterior_____(15)
Anterior Crowding: Max. Arch_____(16) Mand. Arch_____(17)
Crossbite_____(18)
Intercuspation_____(19)
Curve of Spee_____(20)
Overbite (mm)_____(21)
Overjet (mm)_____(22-23)
Mid-lines Coincide_____(24)
Anterior Open Bite_____(25)
Open Contact on Distal of Cuspids_____(26)
Wear Facets of Cuspids_____(27)
Wear Facets on Other Teeth_____(28)
Previously Equilibrated_____(29)
Lateral Excursive Function: Right Side___(30) Left Side___(31)
Centric Relation-Centric Occlusion Slide_____(32)
Protrusive Interference_____(33)
Non-working Interference_____(34)
TMJ Symptoms_____(35)
Patient Brux, Clench, or Grind_____(36)
Muco-gingival Problems_____(37)
ORTHODONTICALLY TREATED_____(38)

(#) is for keypunching purposes

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