ROOT RESORPTION IN MAXILLARY CENTRAL INCISORS

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INTRODUCTION

The occurrence of root resorption has been known to clinical dentists and investigators for many years. The first comprehensive study on apical root loss following orthodontic treatment was done by Ketcham in 1927, and ever since the etiologic cause has been a source of contention.[1] Some suggested etiologic factors include systemic disease, metabolic factors, diet, direction of tooth movement, orthodontic forces, and duration of orthodontic treatment.

Although no cause and effect relationship has been clearly demonstrated, orthodontic tooth movement has been alleged to be a primary cause of root resorption. Incidence varies considerably, 19% to 93.3%, among various investigators. Orthodontic tooth movement is not the only cause of permanent tooth resorption. It has been reported in nonorthodontic patients at incidences ranging from 1 to 84%.

By measuring periapical films from patients before and after treatment, we will attempt to quantitate root resorption and its frequency. The amount of root loss will be compared to other treatment factors such as age, sex, and length of treatment.

LITERATURE REVIEW

Although tooth root resorption had been reported for some years, it was not until Ketcham's[1] articles in the late 1920s that orthodontic tooth movement was directly implicated as a contributing factor. Ketcham's research spans a number of years, and in 1929 he investigated radiographs of 500 patients treated by himself and other orthodontists. He found 19% of these cases showed root resorption of the anterior teeth. Ketcham showed that teeth with resorption prior to orthodontic treatment were markedly more involved on completion. He also noted the most affected area to be the maxillary anteriors and speculated that diet, a pre-existing condition or type of orthodontic appliance might play a role.

In 1930 Marshall,[2] working with histologic evidence of root resorption in monkeys, concluded diet and amount of pressure applied were more pertinent than the type of appliance; however, the relationship of diet to root loss has not been substantiated.

In 1936 Beck[3] reported on 100 patients with severe root resorption, 50 of which had been treated by orthodontics. Eighty-six of the 100 patients had a coexistent endocrine disturbance, usually hypothyroidism. Beck felt that resorption was not caused by orthodontic forces alone. He blamed hypothyroidism and other systemic factors such as cholesterol levels and low basal metabolic rate.

Rudolph[4] compared radiographs of patients who had orthodontic treatment with those who had not and found resorption of teeth in 5 to 14% of the cases who had not had orthodontic treatment. He also reported incidence of root resorption as high as 75% after treatment and that those with longer treatment times showed increased frequency of root resorption. He stated that orthodontic treatment is less hazardous to the root when initiated at an early age.

Hemley,[5] in 1941, reported on 195 orthodontically treated patients, 21% of which showed some degree of root resorption. Hemley alleged that horizontal movement of teeth through bone had a tendency to cause apical root resorption. He also concluded that "the incidence of root resorption can be reduced to the extent that it need not be regarded as a hazard to orthodontic treatment."

Root resorption has been studied histologically by Henry and Weinman[6] on patients who had not undergone orthodontic treatment. They found that 90% of the teeth showed areas of resorption histologically. There was no evidence that inflammation caused resorption, for example, marginal periodontitis. The most common site was the tooth apex. It was concluded that it is "normal but not physiologic for a tooth to incur some root resorption during its life." They also feel that age and trauma were contributing factors.

Rygh,[8] using electron microscopy techniques, concluded that root resorption takes place after elimination of hyalinized tissue because of the loss of barriers formed by mature periodontal collagen fibers and the cementoid layer, therefore leaving a denuded cemental surface

without a barrier. It was hypothesized that such an area was readily attacked by odontoclasts once a resorption lacunae had been established. The events following depended on whether or not orthodontic force was applied. If orthodontic force was discontinued, the resorption lacunae were repaired.

Massler and Malone[9] studied the resorption potential of permanent teeth by analyzing 708 nonorthodontic patients. They found all patients exhibited root resorption and that 86% of all teeth were involved. In a second group of 81 orthodontically treated patients, they found inherent conditions were worsened with orthodontic treatment (.11 in nontreated to .14 in treated patients) as compared by severe resorption (4 mm to 1/4 of root length).

Phillips[10] studied root resorption of 69 orthodontically treated cases. Using intraoral radiographs taken before and after treatment, he assigned values of (1) slight: minimal blunting of the root apices, (2) moderate: up to 1/4 root length loss, (3) excessive: over 1/4 root length loss, and (4) questionable: possible traces not positively identifiable. He found 39% of all teeth showed some involvement. Maxillary central incisors were most common at 84%, followed by maxillary lateral incisors at 83%, mandibular central incisors and lateral incisors at 72 and 64%, respectively. Using lateral headfilms, he measured types and amounts of maxillary central incisor movement and concluded that there was no correlation between resorption and age at start of treatment, length of treatment, amount of tooth movement and amount of movement of apices lingually. Additionally, surface area studies showed a loss of

2 mm of root apex, reduced by 5 to 10% the area for periodontal attachment.

Deshields[11] studied 24 males and 28 females whom before treatment exhibited no evidence of tooth resorption; but at the end of treatment, all but one had radiographic evidence of tooth resorption. He concluded that: (1) sex was not a likely factor in predisposing an individual to root resorption, (2) length of treatment and type of mechanics used can be related to the severity of root resorption, and (3) severe resorption may contribute to premature loss of the affected teeth.

Morse,[12] in 1970, quantified the extent of tooth resorption treated by fixed appliances and reported an average of 2.73 mm loss of root length among 34 cases with ranges of .5 to 5 mm. Stolien and Zachrisson[13] measured a mean difference of 1.52 mm in before and after treatment measurements in 59 Class II div. 1 cases. Ronnerman and Larson[14] assessed apical root resorption of maxillary central incisors in a 10-year follow-up study. Fourteen cases (61%) had zero or less than 1 mm root loss; nine cases (39%) had between 1 and 3 mm; and apical root resorption, more than 3 mm was not found. They also noted that no further apical resorption seemed to continue after completion of active orthodontic treatment and the incidence of root resorption was low when removable appliances were used.

Brown,[17] in 1983, suggested permanent tooth root resorption was a normal phenomenon. He concluded that Sharpey's fibers, penetrating the cementum and cementoblasts, form a physical barrier which under normal circumstances acts as an effective barrier to keep osteoclasts away from

the root surface, but this barrier is least effective in the region of the root apex due to a smaller number of Sharpey's fibers that arise from the apical third of the root cementum.

A major problem for all investigators has been the difficulty of obtaining accurate measurements of root length because of radiographic errors and angulation position changes. Also, the vast majority of reports deal with retrospective data. Attempts have been made to standardize measurement techniques.[19]

A review of the literature points out that root resorption is a universal problem to all orthodontists. There is no consensus in the literature with regard to etiology or treatment considerations to prevent or minimize root loss.

MATERIALS AND METHODS

This sample consisted of 185 patients treated at the orthodontic clinic of the Oregon Health Sciences University. Cases were selected at random from the clinic files on the basis of completeness of the periapical radiographic records. All types of malocclusions were selected, and of those, 135 were females and 50 were males. An additional 15 patients were not used in this study for various radiographic reasons, i.e., severely rotated central incisors, incomplete root apex formation, root apex off the film, poor radiographic quality and overlap of the central incisors. All patients used in the sample had periapical radiographs taken before and after treatment and had intact and undamaged central incisors. All radiographs were exposed by the same technician using a bisecting angle technique.

Both right and left central incisors were measured on the periapical radiographs, before and following orthodontic treatment, with a vernier caliper reading to the nearest 0.1 mm. The anatomical crown was measured from the most superior point on the cemento-enamel junction on the facial surface to the incisal edge. The root was measured from the most superior point on the cemento-enamel junction to the apex of the root. The total length of the central incisor was the sum of the crown and root lengths. No magnification factors were corrected. To minimize problems of magnification, foreshortening, elongation or

inconsistent radiographic technique, a root length ratio was calculated. The ratio was determined by dividing the root length by the total tooth length.[7]

From the patient's treatment record, the length of treatment time was recorded as the time between first wire placement and retention of these teeth at the end of treatment. Age of start and finish of treatment were recorded to the nearest month.

For an error determination replicate measures were done on 30 patients randomly selected from the group. The crown to root ratios were used and a standard error of the measure was computed utilizing the formula:

$$S.E.Measure = \sqrt{\frac{\Sigma d^2}{2n}}$$

The paired t test was used to determine statistical significance between right central incisors before and after treatment, left central incisors before and after treatment, right and left central incisors before treatment, and right and left central incisors after treatment, and the amount of root loss.

The mean differences, the variation, standard deviation, standard error of the mean and coefficient of variation were determined for right and left central incisors.

The chi-square test was utilized to test if a relationship existed between males and females and amount of root loss determined by the differences in crown to root ratio before and after treatment. Three

groups were determined based on the amount of root resorption by dividing the range of net crown to root ratio change by 3, resulting in mild (0 to .05), moderate (.06 to .10) and severe (.11 to .17) root loss. A chi-square analysis was also utilized to determine if a relationship existed between male children, male adults, female children, female adults, and the three previously determined grades of root loss. Female adults were those who at the end of treatment were at least 16 years old, and male adults were at least 18.

Percentages were determined for male and females with zero, mild, and severe root resorption. The zero change in crown to root ratio included those net changes before and after treatment plus two standard error of the measures, therefore removing those patients with a crown to root ratio net change of 0.00 to 0.01 from the mild group.

Correlation coefficients were determined for length of treatment in female children and adults, male children and adults, and age at end of treatment and the amount of root resorption.

FINDINGS

The paired t test demonstrated that the right central incisor was statistically different from its beginning length after treatment. The same was true for the left incisor (Table I). The computed value of 18.56 and 19.80 exceeded the table value of 1.64 at the .05 probability level utilizing a one-tailed test. Furthermore, the right incisor was not statistically different from the left before treatment commenced. There was also no statistical significance between the incisors at termination of orthodontic therapy (Table I).

Using the before and after crown to root ratios for the right and left central incisors, the mean difference, variation, standard deviation, standard error of the mean, and the coefficient of variation were computed (Table II).

The mean, median, and mode were determined for the right and left central incisors before and after treatment. The mean crown to root ratio before treatment was 0.541 right and left and after treatment 0.492 right and 0.489 left (Table III). Histograms were constructed to visually portray the incidence of root resorption (Figure 1).

The chi-square test was used to determine if a relationship exists between males and females and the amount of root loss. The computed value at the 0.05 level of probability was greater than the table value

so we conclude that males and females do exhibit a relationship between sex and the amount of root loss (Table IV). The chi square was also used to determine if a relationship existed between male and female children and adults and the degree of root resorption. The computed values for the male and female children and adults exceeded the table value (Table IV).

Histograms were also used to depict the varying degrees of root resorption as categorized earlier into mild, moderate, and severe root loss for the entire sample and to the length of treatment for both male and female children and adults (Figures 2 and 3).

Tables were also made to depict the percentage for males and females with zero, mild, moderate and severe root resorption (Table V).

Correlation coefficients were computed in male and female children and adults for length of treatment, age at the end of treatment, and the amount of root resorption. The correlations were all found to be very low, the largest being 0.323 for the length of treatment in female children (Table VI).

The standard error of the measure was 0.0068 for the crown to root ratio of the right and left central incisors before and after orthodontic treatment.

DISCUSSION

The problem of root resorption during orthodontic treatment was examined and compared to the treatment variables: age, sex and the length of treatment, in an effort to gain a better understanding of this complex phenomenon. The sample size of 185 treated patients was selected in an attempt to minimize the effect of possible variation extremes. Careful effort was made to select cases at random, as long as adequate periapical radiographs were available before and after treatment. Since root resorption is a universal problem, a random selection of 185 patients was thought to be adequate; however, a larger sample may be needed to express the biologic variability.

We found no significant difference between the right and left central incisors before treatment. Statistical significance was noted for right and left central incisors testing before treatment and after treatment (Table I). The statistical data associated with the crown to root ratios in Tables II and III demonstrate the similarity of right and left central incisors before treatment, 0.54, and after treatment, 0.49. The mean difference for right central incisors was 0.048 and left was 0.049. The coefficient of variation was low: 0.072 and 0.068 for right and left central incisors. Low coefficient of variation denotes a higher predictive value.[16] The incidence of root resorption shown in Figure 1 shows the differences in distribution of before and

after treatment ratios. The after treatment ratios are apparently skewed to the left (negatively). The mean ratios and the range of ratios show no apparent differences. Except for the skewed portion of the postorthodontic group, the distribution of the three groups does not show any marked difference.

The techniques used in this study do possess error. The magnitude of this study plus the use of ratios appear to randomly distribute the error. The mean root length ratio of 0.54 for preorthodontic treatment is very similar to G. V. Black's mean dental measurement for central incisors (0.53). Plets also had a crown to root ratio for his non-orthodontic and preorthodontic cases of 0.52 for central incisors. The postorthodontic group (0.495) of Plets also was similar to our after treatment group (0.491).[7]

Examination of Table V shows the percentages of root resorption incidence grouped into mild, moderate, severe and zero root resorption. Sixty-six percent of the females showed zero to mild root resorption, as did 67% of the males. Of these percentages the distribution of female children demonstrated a 20% incidence for zero resorption compared to adult females with 8%. The females with mild resorption were closer at .495 in children to .52 in adults. Thirty percent of the females had moderate resorption with little difference between children and adults. Severe resorption was about 5% in female adults, demonstrating twice the frequency of the children. An examination of the males showed a higher incidence of zero root resorption and lower incidence of moderate resorption in adults. No severe male cases of root resorption were noted in this study. Overall, the males had a higher

incidence of moderate resorption. It was hoped that some correlations of value could be gained to help identify a group or groups of individuals who may have moderate to severe resorption. From this study's data, none could be found. The incidence of root resorption was fairly equal for males and females, and children and adults. Based on our findings, no clinically significant differences between sexes in any of the variables existed. The sample was heavily weighted to females (135 females to 50 males) but probably reflects the ratio found among orthodontic patients in this treatment facility.

The chi-square test (Table IV) was used to determine if the amount of root resorption was independent of sex or age. In both cases, the hypothesis of independence is rejected at the 5% level of significance. A relationship of dependence does exist according to our data with the amount of root resorption, the sex of the patient, and the age of the patient, although it does not tell us what kind of relationship exists.

The assumption has been made by some investigators[4,8,11,14] that orthodontic forces acting on a tooth are causing root resorption and length of treatment may contribute to severity. Although very low, the correlation coefficient for length of treatment to amount of root loss was the highest of those examined (Table VI). Comparing cases with mild, moderate and severe resorption (Figure 3), no significant difference in treatment time was found. The recorded length of treatment only approximates the time of actual tooth movement force. Depending on the mechanics used, skill of the orthodontist, and distance through which the tooth is moved, some patients will have greater and longer acting forces than others for similar length of time banded.[15]

Correlation coefficient for age at end of treatment to amount of root loss was very low. The highest being .282 for male adults. Percent frequency (Table V) also suggests no meaningful difference with the age at end of treatment, as adults and children showed similar distribution for amount of root loss.

The findings of this study suggest that most patients' root lengths were not significantly shortened by routine orthodontic care. Even though 36% of all patients showed moderate to severe resorption, only 4% showed severe root loss. The patients who exhibited significant root resorption did not demonstrate any of the specific treatment variables studied. No conclusive data exists that would enable a clinician to predict the occurrence of root shortening prior to orthodontic treatment.

If the loss of 1 to 2 mm of apical root structure with associated 5 to 10% reduction in retentive surface is insignificant, as suggested by Phillips,[10] what is the significance of root shortening in orthodontic patients? The effect on the dentition is difficult to evaluate; but as more and more of the population has increasing availability to orthodontic services, it seems that loss of root structure may contribute to early loss of teeth when complicated by recession and bone loss from periodontal disease.

The use of crown to root ratio, while minimizing the error of radiographic distortion, offers another means for identifying short roots other than the use of root morphology. Preorthodontic patients starting with short roots may have a tendency toward further shortening of roots during orthodontic procedures.[1,9] If the loss of approximately

2 mm of root structure would jeopardize the bone support of the tooth, the benefit of treatment should be carefully reconsidered. Whenever fixed appliances are used, comprehensive apical radiographs should be obtained before treatment begins and then at intervals of time determined by the nature of the movements being undertaken.

SUMMARY AND CONCLUSIONS

This study was an attempt to gain relative information regarding root resorption in orthodontically treated patients. Measuring dental radiographs incorporates problems due to enlargement, distortion and angulation errors which further compounds the difficulty in quantifying these measurements. In this study four out of five patients exhibited some degree of root resorption which supports evidence that it is a universal problem.

From this study the following conclusions can be made:

1. Central incisors subjected to orthodontic treatment will probably exhibit some degree of root resorption.
2. Males and females show no difference in root loss.
3. There will be approximately 4% loss of crown to root ratio following orthodontic treatment.
4. The correlation coefficients for root loss and length of treatment were not clinically useful.
5. The correlation coefficients for root loss and age were not clinically useful.

Root resorption due to orthodontic treatment rarely results in tooth loss but the widespread nature of the problem definitely warrants further investigation.

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FIGURE 1 ROOT RESORPTION INCIDENCE

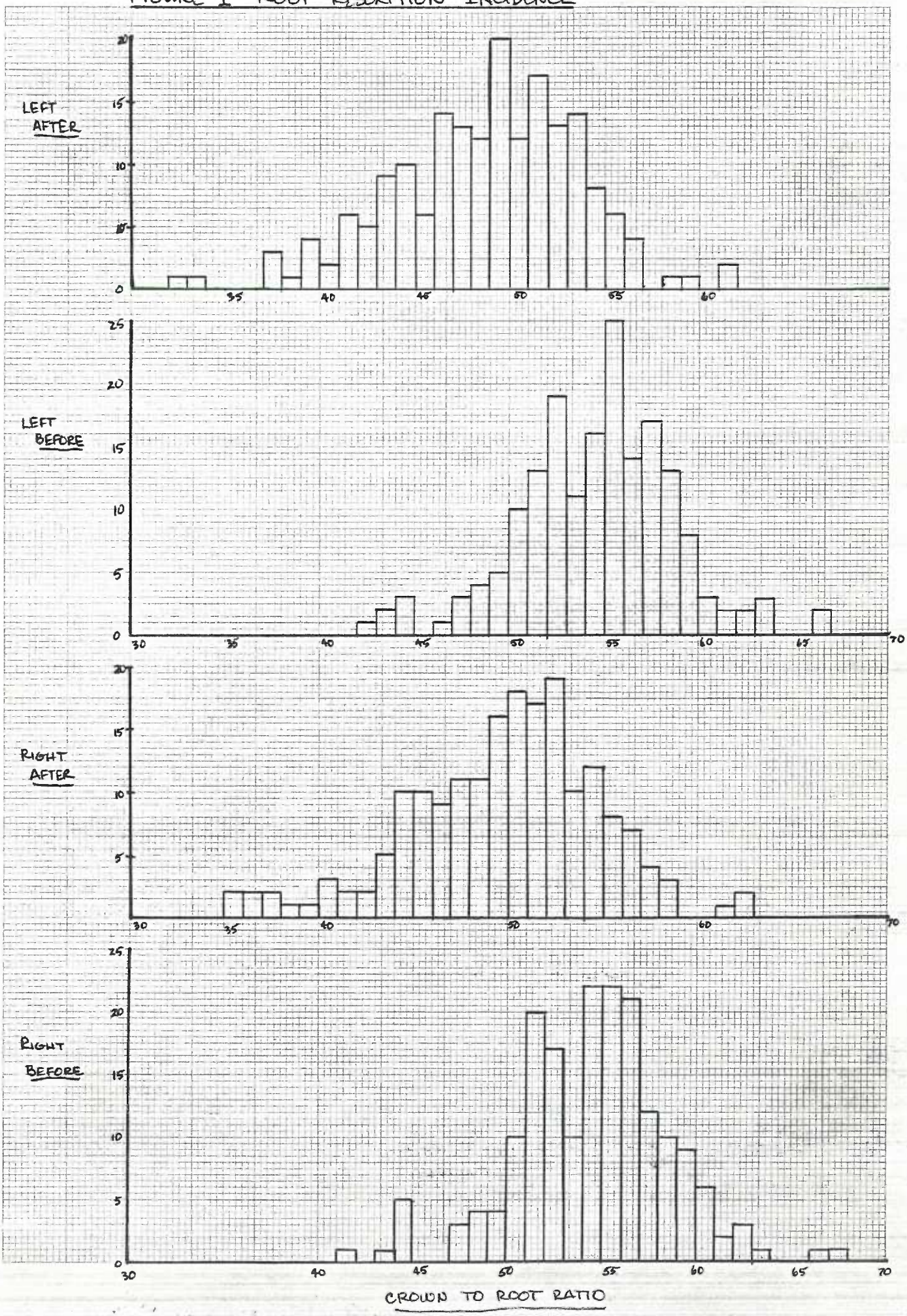

FIGURE 2 ROOT LOSS

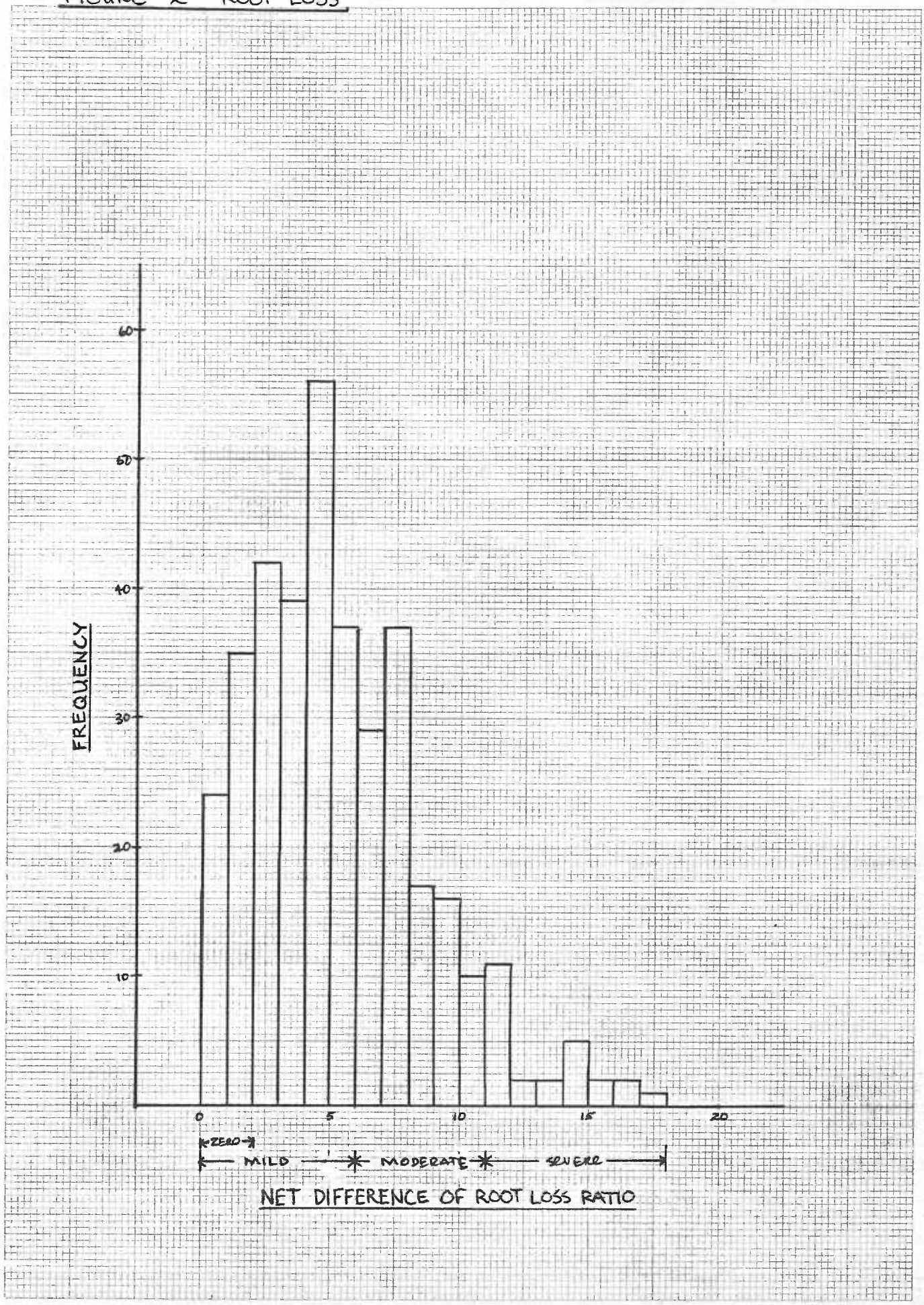

FIGURE 3 LENGTH OF TREATMENT

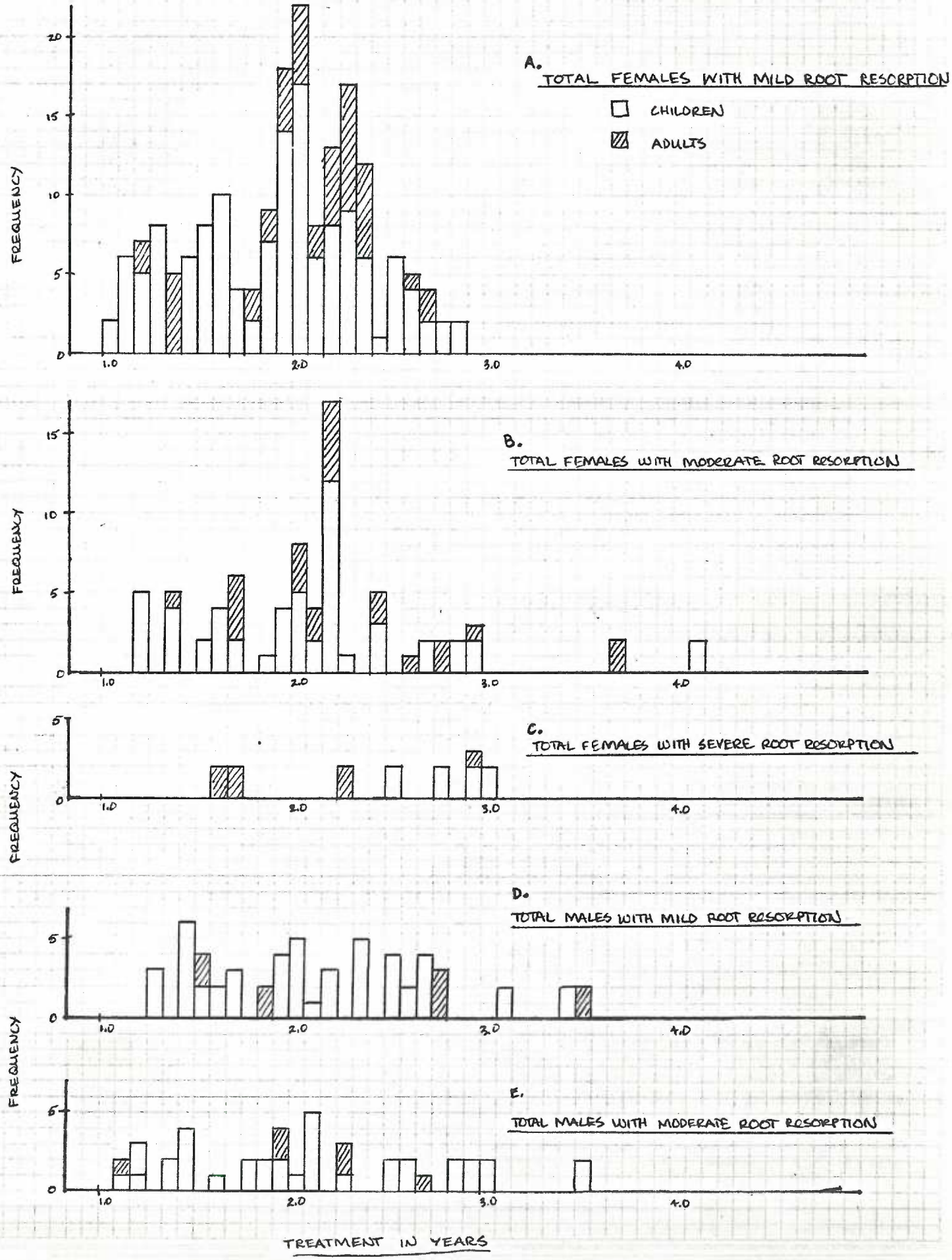

TABLE I

Statistical Data from the Root Resorption Study Sample (N = 185)

Student t Test Values of Central Incisor Before Treatment and After Treatment

	V	t
Rights, before and after	184	18.56
Lefts, before and after	184	19.80
Rights and lefts before	184	0.157
Rights and lefts after	184	0.836

TABLE II

Statistical Data Associated with Mean Differences of Crown to Root Ratio

	$\bar{dx}$	s^2	s	SEM	CV
Right	0.0475	0.0012	.0034	.0025	.072
Left	0.0489	0.0011	.0033	.0024	.068

TABLE III

Statistical Data Associated with Crown to Root Ratio

	$\bar{x}$	Median	Mode	s^2	s	SEM
Right before	.541	.54	.545	.0017	.041	.003
Left before	.541	.54	.55	.0017	.041	.003
Right after	.492	.50	.52	.0025	.050	.003
Left after	.489	.50	.50	.0036	.060	.004

TABLE IV

Chi Square for Males and Females, Children and Adults and Mild, Moderate and Severe Classifications

	x^2
Males	8.14
Females	3.04
Males and Females	10.53
Male Children and Adults	27.6
Female Children and Adults	15.7

TABLE V

Percentages of Zero, Mild, Moderate and Severe Root Resorption

		Zero	(.02-.05) Mild	(.06-.10) Moderate	(.11-.17) Severe
Female	Children	20	49.5	27	4
	Adults	8	52	30	9
	Total	16.3	50	28	5.6
Male	Children	11	46	43	0
	Adults	15	46	38	0
	Total	12	46	42	0
Total		18	49	32	4

TABLE VI

Correlation Coefficients of the Root Resorption Study Sample

	r
Length of Treatment to Amount of Root Loss	
Female Children	.323
Female Adults	.0039
Male Children	.119
Male Adults	.286
Age at End of Treatment to Amount of Root Loss	
Female Children	.102
Female Adults	.052
Male Children	.040
Male Adults	.282