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ROOT FORM AS AN AID IN THE DIAGNOSIS AND PREDICTION OF EARLY-ONSET PERIODONTITIS

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A research report submitted to the Faculty of Health Sciences, University of Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Dentistry in the branch of Periodontics and Oral Medicine.

Johannesburg, 1998

DECLARATION

I, Robert John Childs, declare that this research report is my own work. I submit it for the degree of Master of Dentistry in the branch of Periodontics and Oral Medicine of the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Signed: .....

30th day of MARCH, 1998

The University of Witwatersrand, Johannesburg, Human Ethical Committee Clearance number : M980211

DEDICATION

To my wife Grace

for all your inspiration, support,

patience and remarkable endurance.

ABSTRACT

This study was undertaken to investigate the observation that in some subjects with early-onset periodontitis there is a peculiar tapering slenderness of root form. This study compares the degree of taper of the roots of maxillary second premolars, and of the distal roots of mandibular first molars of patients with early-onset periodontitis (*experimental* subjects), with that of the corresponding roots of *control* subjects. It seeks to determine whether the degree of taper is ascribable to a particular part of the root; whether differences if any are related to gender or to race; and whether the molars or the premolars would be better diagnostic aids to, and predictors of disease.

Periapical radiographs of twenty teeth of each type were selected for the *experimental* and *control* groups. Accurate large scale tracings of the root outlines were made from radiographs. Using the mesiodistal widths of the roots at the cemento-enamel junction in the case of the premolars, and at the root bifurcation in the case of the distal roots of the molars as baseline measurements, the degrees of taper of the roots were determined.

Statistical comparison of the degrees of taper of roots from *experimental* subjects with those of the roots of *control* subjects

showed strong evidence of a sharper degree of taper in the former; this was more pronounced for the premolars than for the molars. The degree of taper was more marked in the apical half of the roots of *experimental* molars; but in *experimental* premolars the increased taper was evident throughout the entire length of the root.

In the case of the *experimental* molar roots, there is a relationship between race and the degree of taper: this highlights the desirability of future studies examining the root forms of racially segregated groups. There is no relationship between gender and the tapering of the *experimental* molar roots.

For premolars the increased taper of *experimental* teeth is related neither to race nor to gender. Prediction and diagnosis of disease is more reliable with premolars than with molars, because the latter taper more sharply only along a portion of their roots.

In an affected individual, the maxillary second premolar appears to be a reliable predictor and an indicator of early-onset periodontitis. The distal root of the mandibular first molar likewise is a predictor and an indicator of early-onset periodontitis; but as its degree of taper is less pronounced and occurs only in the apical half of the root, its reliability in these roles may be diminished.

ACKNOWLEDGEMENTS

I wish to thank my supervisor Professor John Lemmer, Head of the Department of Oral Medicine and Periodontology, for sharing his valuable expertise, time, kindness; for his encouragement, continued support and patience in the writing of this report. My sincere thanks go to Professor John and Mrs Joan Lemmer who were extremely generous in their hospitality during our many meetings.

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INTRODUCTION

It has long been recognized that there is a form of periodontal disease which is characterised by its onset at a relatively early age, by its aggressive, destructive progression, and by its resistance to conventional periodontal treatment. In 1938 Wannenmacher[1] gave a good description of this disease and called it *paradontitis marginalis progressiva*. Over the years a number of names have been given to this type of periodontal disease, and it's aetiology and pathogenisis have been much debated. Amongst the names are: periodontosis, precocious advanced alveolar bone atrophy, Gottlieb syndrome, periodontosis with periodontitis, precocious periodontitis and periodontitis complex.

It was only natural that parallel to this plethora of terminologies there was likewise a proliferation of theories as to the aetiology and pathogenisis of the condition. Orban and Weinman[2] emphasised that this form of periodontitis was a 'degenerative' and perhaps a systemic disorder. Causes were sought in the structure of the periodontal ligament, in the quality of the bone, and in the character of the cementum (the so called 'cementopathia').

In 1966 the World Workshop in Periodontics[3] concluded that the concept of periodontosis as a degenerative entity was unsubstantiated, and that the term periodontosis should therefore be eliminated from the 'authorised' periodontal nomenclature. However, it was recognized that a pattern of periodontitis different from

common periodontitis might occur in young adults and adolescents.

During the 1960's the terms 'periodontitis complex' and 'periodontitis simplex' fell into disuse and thereafter, until the 1980's, the most common diagnostic term for all types of periodontitis was chronic marginal periodontitis. A subclassification was introduced by The American Academy of Periodontology, which differentiated chronic marginal periodontitis into case types I, II, III and IV, on the basis of severity of the periodontal destruction. These subtypes did not represent separate diseases but the definition of subtypes provided a means of improving communication[6].

The term juvenile periodontitis was coined by Chaput *et al* in 1967, introduced to the literature by Butler[4] in 1969, and defined by Baer[5] in 1971 as "a disease of the periodontium occurring in an otherwise healthy adolescent and .... characterised by rapid loss of alveolar bone about more than one tooth of the permanent dentition."

In 1982 Page and Schroeder proposed a classification of periodontitis with five distinct types [7,8,9,] :

Prepubertal periodontitis	Early-onset periodontitis
Juvenile periodontitis	
Rapidly progressive periodontitis	
Adult periodontitis	
Acute necrotizing periodontitis	

and introduced the term early-onset periodontitis to include the three types of periodontitis that affected younger persons .

This classification was a departure from earlier classifications in that it was based on a number of criteria including age, pocket flora, leukocyte function tests, serum antibodies, clinical and radiographic features, rates of progression, and history. Despite the complexity of the underlying pathological processes, the classification was deliberately kept simple in order to accommodate additional forms of disease should new understanding be gained or should additional forms of periodontitis be identified[6].

In 1989 the American Academy of Periodontology[6] recommended that early-onset periodontitis with its subtypes should form part of a new classification[10] (fig 1).

I. ADULT PERIODONTITIS

II. EARLY-ONSET PERIODONTITIS

a. Prepubertal periodontitis

b. Juvenile periodontitis

c. Rapidly progressive periodontitis

III. PERIODONTITIS ASSOCIATED WITH SYSTEMIC DISEASE

IV. NECROTIZING UL[illegible]RATIVE PERIODONTITIS

V. REFRACTORY PERIODONTITIS

Figure 1. CLASSIFICATION OF PERIODONTAL DISEASES ACCORDING TO THE AMERICAN ACADEMY OF PERIODONTOLOGY (1989)

It was soon realised that there was considerable overlap of some features of these diseases and that certain host responses were common to more than one category.

The term early-onset periodontitis has stood the test of time and has been incorporated into several classifications of periodontal diseases, including those of Grant, Stern, and Listgarten 1988[11], Ranney 1993[12] (Figure 2) and Carranza 1995[13].

GINGIVITIS
- Gingivitis, plaque bacterial
  - Non-aggravated
  - Systemically aggravated
    - Related to sex hormones
    - Related to drugs
    - Related to systemic disease
- Necrotizing ulcerative gingivitis
  - Systemic determinants unknown
  - Related to HIV
- Gingivitis, non-plaque
  - Associated with skin disease
  - Allergic
  - Infectious

PERIODONTITIS
- Adult periodontitis
  - *Non- aggravated*
  - Systemically aggravated
    - Neutropaenias
    - Leukaemias
    - Lazy leucocyte syndrome
    - AIDS
    - Diabetes mellitus
    - Crohn's disease
    - Addison's disease
- *Early-onset periodontitis*
  - Localised early-onset periodontitis
    - Neutrophil abnormality
  - Generalised early-onset periodontitis
    - Neutrophil abnormality
    - Immunodeficient
    - Early-onset periodontitis related to systemic disease
      - Leukocyte adhesion deficiency
      - *Hypophosphatasia*
      - Papillon-Lefevre syndrome
      - Neutropaenias
      - Leukaemia
      - Chediak-Higashi syndrome
      - *AIDS*
      - Diabetes mellitus type 1
      - Trisomy 21
      - Histiocytosis X
      - Ehlers-Danlos syndrome
    - Early-onset periodontitis systemic determinants unknown
- Necrotising ulcerative periodontitis
  - Systemic determinants unknown
  - Related to HIV
  - Related to nutrition
- Periodontal abscess

Figure 2. RANNEY'S CLASSIFICATION OF PERIODONTAL DISEASES (1993)

The classification of Page and Schroeder and that of the American Academy of Periodontology implied clear distinctions between the different periodontal diseases; but in practice it is often difficult to draw these distinctions, particularly within the group designated early-onset periodontitis. This difficulty is reflected in the classification of Ranney, who eliminates the prepubertal, juvenile and rapidly progressive types of Page and Schroeder and of the

American Academy of Periodontology, and simply substitutes the much broader grouping of early-onset periodontitis , with localised, and generalised forms. On the basis of clinical and laboratory evidence, Ranney argues that localised juvenile periodontitis, generalised juvenile periodontitis, rapidly progressive periodontitis, and pre-pubertal periodontitis, may well be variations of the same disease[12]. Ranney's classification also allows the possibility that localised and generalised early-onset periodontitis can overlap and may represent facets of the same disease[12]. Armitage[14] makes the point that despite the fact that these classifications have promoted a clearer understanding of the heterogeneity of periodontal infections, revision of the current classification system is needed[14].

A problem far greater than that of distinguishing between the different types of periodontitis, is that of predicting susceptibility to periodontitis and in particular to early-onset periodontitis. Although certain defects in neutrophil function in early-onset periodontitis are well recognised, to date it has not been shown that these can be used as predictors of early-onset periodontitis and even if they could, it would often be impractical. There are well established differences between the flora associated with adult periodontitis and that associated with early-onset periodontitis, but these differences become apparent only once the disease is established, and thus no predictive value can be attached to these differences.

Forces generated by muscles of mastication were at one time

supposed to be significant in influencing the onset and progression of periodontitis (occlusal traumatism); but despite whole schools of thought in occlusal reconstruction being based upon this hypothesis, little or no scientific evidence has ever come to light in support thereof.

While crown and root morphology (developmental grooves, cervical enamel projections), tooth arrangement, and poor-quality restorations and prostheses continue to be implicated in promoting plaque accumulation, variation in root morphology *per se* has not been shown to have any role in the aetiology of periodontitis [15]. In a recent study by Hou, Tsai and Huang[15], it was noted that there was a significant relationship between fused molar roots and localised periodontitis. They drew particular attention to the tapering shape of the roots at diseased sites as compared to healthy sites; but did not show that these tapering roots are significantly different from 'normal' roots [15].

For several decades, staff members of the Department of Oral Medicine and Periodontology at the University of the Witwatersrand, Johannesburg, had noticed that patients with early-onset periodontitis often seem to have peculiarly tapering or slender tooth roots. However, only in 1993 was an investigation into this subjective observation undertaken, and Marnewick published the results in the form of an MDent research report[16]. As far as we can determine, other than the clinical observation in the recent study of

Hou et al (1997)[15], no specific reference to the tapering of roots of teeth in relation to early-onset periodontitis appears in the literature.

It is difficult to postulate any mechanism whereby a sharply tapering root form could contribute to the pathogenisis of early-onset periodontitis. One might guess that root form could be related to an undefined abnormality of cementum, and that both root form and cemental defect could be ascribable to an early developmental aberration. Similarly one might postulate a genetic trait governing both root form and say, deficient leukocyte function. Diminished root surface area as a factor, as referred to by Hou et al[15], and Marnewick[16], predicates occlusal forces[17,18] as a co-factor, a debate which has long since been put to rest.

Intra-oral radiography provides a test of relatively high specificity which can confirm the presence of disease and reveal a 'history' of hard tissue changes[10b]. If it could be established that there is a positive relation between unusual root form and a particular form of periodontitis, then the radiographic image could be a highly specific means of prediction of that disease and might also be a valuable aid to diagnosis.

Using radiographs taken from departmental record files, Marnewick studied the degree of taper of upper central incisors and lower first premolars. He showed a clear and statistically highly significant difference between the taper of these teeth in subjects with early-

onset periodontitis as compared with that of teeth of age matched patients with healthy periodontia, or with no more than gingivitis. The affected teeth tapered more sharply than the control teeth.

In the case of the upper central incisors the difference in taper was ascribable entirely to the sharp taper in the apical portion of the root ($P = 0{,}0331$ Hotelling's T^2); but in the case of the lower first premolars the entire roots tapered more sharply than the controls ($P = 0{,}0002$ Hotelling's T^2).

While the significance of this observation in aetiological terms is obscure, it could help to distinguish early-onset periodontitis from adult periodontitis, and particularly from the refractory form of adult periodontitis. It could also have value as a predictor of early-onset periodontitis since the peculiarities of root morphology can be observed radiographically long before the onset of periodontal disease.

The present evidence relating to the sharper taper of roots in early-onset periodontitis is derived from a study of two tooth types only, namely upper central incisors and lower first premolars. The demonstration of a degree of taper greater than the normal in other teeth of subjects with early-onset periodontitis is therefore necessary to confirm that the observation is generally valid, and to broaden the baseline of reference for this feature as an aid to diagnosis, and as a predictor of disease.

AIM

The aim of this study is to compare the degree of taper of roots of teeth other than those previously studied by Marnewick (1993), in order to determine whether the results of the earlier study can be validated with other tooth types. The roots of maxillary second premolars and the distal roots of mandibular first molars of patients with early-onset periodontitis will be compared with those of *control* subjects, because these particular roots offer good radiographic imaging. At the same time I will try to find out whether any differences which may be demonstrated are related to gender or to race, and whether the degree of taper is ascribable to a particular part of the root.

MATERIALS AND METHODS

Material selection

Files of forty patients diagnosed as suffering from early-onset periodontitis were drawn randomly from records of the Department of Oral Medicine and Periodontology, University of the Witwatersrand, Johannesburg. The forty selected record files from which the *experimental* material was drawn, included medical and dental histories, periodontal probing depths, all other details of the clinical examination, results of special tests if done, and a full set of periapical radiographs taken using the 'parallelling' technique. Periapical radiographs of twenty teeth of each type, (maxillary second premolar and mandibular first molar), were selected from these files on the basis of the quality of the radiographic images. A radiograph of only one of the tooth types was taken from each of the forty files. The diagnoses of early-onset periodontitis had been made by, or under the supervision of clinicians experienced in the field of periodontics, primarily on clinical and radiographic grounds; but in several patients, with the additional evidence of microbiological investigations. The sample comprised cases of juvenile periodontitis and rapidly progressive periodontitis; no cases of prepubertal periodontitis were found.

A further forty files comprising cases of patients with healthy periodontia who may for instance have had elective crown lengthening procedures, together with cases of patients with no

more than marginal gingivitis were chosen for the *control* group. One periapical radiograph of either a maxillary second premolar or a mandibular first molar was taken from each of these files, the selections again being on the basis of the good quality of the images.

Criteria for the selection or exclusion of *experimental* subjects/ radiographs

1. Subjects must have been diagnosed as having one of the forms of early-onset periodontitis, according to accepted criteria.
2. Only files of subjects thirty-five years of age and younger were selected, because according to the literature[7, 10b, 19] , the aggressive early-onset forms of periodontitis are uncommon after the age of thirty-five years, while adult periodontitis increases in prevalence.
3. Subjects with a history of any condition or accident that may have affected the development of any of the teeth, or who may have had orthodontic treatment, were excluded.
4. Radiographs of teeth which were non-vital or root-treated were excluded.
5. Only one tooth type per subject was included in the study.
6. The teeth of which radiographs were selected, all had periodontal probing depths of 5mm or more.

Criteria for the selection or exclusion of *control* subjects/ radiographs

1. Only subjects of thirty-five years of age and younger were selected in order to have a *control* group reasonably age matched with the *experimental* group.
2. Criteria 3-5 as above.
3. Selected radiographs were of subjects free of periodontal disease, or with no more than marginal gingivitis.

Methods

TRACINGS

A Makroskop model 420* and a Panasonic F10 Mark II Video Camera**, were used to display the radiographs on a computer screen.

Of all the selected radiographs, the radiograph of the tooth which appeared to have the longest root was placed on the platen of the Makroskop which was then adjusted so that the image on the computer screen was as sharp and as large as possible. This was done to ensure that all the subsequent images (which would thus be of teeth with shorter roots) would be accommodated on the screen.

The settings of the Makroskop were recorded, and reset at each use

*Wild, Heerbrügg, Switzerland.

**Matsushita Communication Industrial Company Ltd., Japan.

to ensure accurate standardised magnification of all radiographic images studied. As an additional magnification check, a piece of stainless steel wire measuring 2.0cm in length was then placed on the platen, and the size of it's image, measured on the computer screen, was 16.8cm. This piece of wire was subsequently used each time the Makroskop was reset, to confirm the accuracy of the resetting.

This standardization of magnification was largely for the convenience of having similar-sized images to measure. In fact, there would certainly have been some variation in magnification when the original radiographs were taken, owing to small differences in radiographic technique; but since all the measurements were to be reduced to proportions, magnification was not really very important.

Each radiographic image was carefully traced with a finely pointed pen (0.3mm) onto a sheet of transparent film secured to the computer screen. In the case of the premolars, the cemento-enamel junction-points were located on the radiographic images, and marked with dots (fig. 3.1, page 16). Age, gender, race, tooth number and denoted group (*experimental* or *control*) were recorded on the film. Each tracing was then placed over a sheet of translucent graph paper on a horizontal viewing box for marking.

MARKING OF MAXILLARY SECOND PREMOLARS

On each enlarged tracing, a line was drawn across the width of the root joining the previously marked cemento-enamel junction-points. This baseline was designated as A ... A^1 (fig. 3.2, page 16) .The mid;oint of this baseline was marked and thereafter, with the help of the graph paper, the midpoints of the root were marked on the tracings at 5mm intervals to the apex. These points were joined by a line drawn using a flexible ruler. This central line was designated the root axis line (fig. 3.3, page 16).

Next, again with the help of the millimetre graph paper, the central axis line was marked into ten equal divisions. A line perpendicular to the central axis line was then drawn at each of these nine points, across the width of the root. The lines were designated as shown in figure 3.4.

MARKING OF MANDIBULAR FIRST MOLARS

For the mandibular first molars, only the distal roots were considered. In each case the baseline was taken as the shortest distance from the most coronal point of the bifurcation (point A), to the closest point of the distal surface of the distal root, as determined with compasses (fig.3.5, page 17). Since this line was to be used as a baseline for a series of proportional measurements its accuracy was of no great consequence. Thereafter the tracing was marked as for a premolar (fig.3.6, page 17).

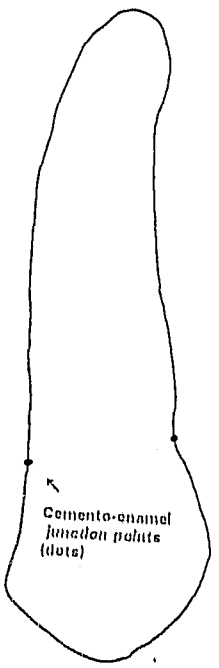


Figure 3.1

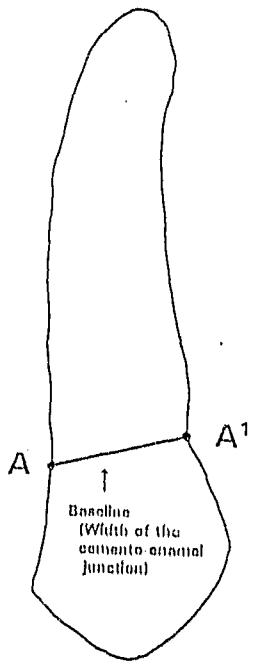


Figure 3.2

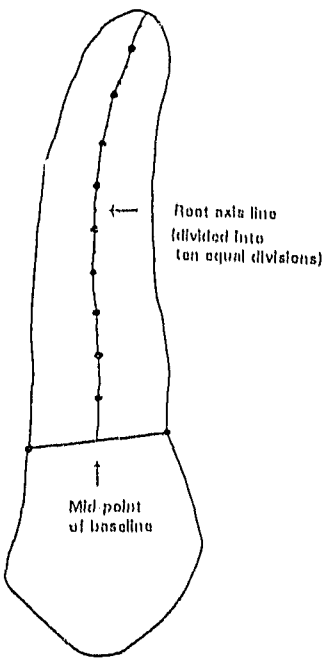


Figure 3.3

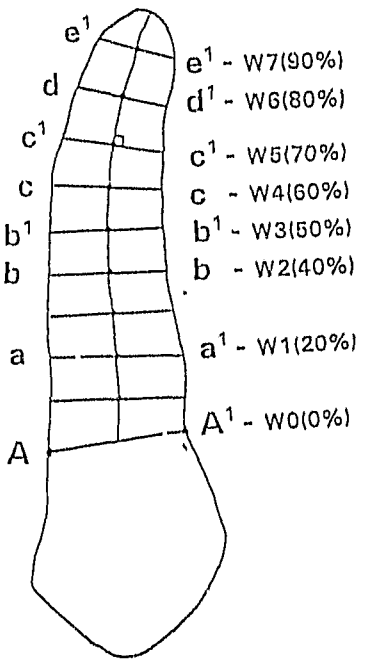


Figure 3.4

Figures 3.1, 3.2, 3.3, 3.4 METHOD OF MARKING PREMOLAR TRACINGS FOR MEASURING

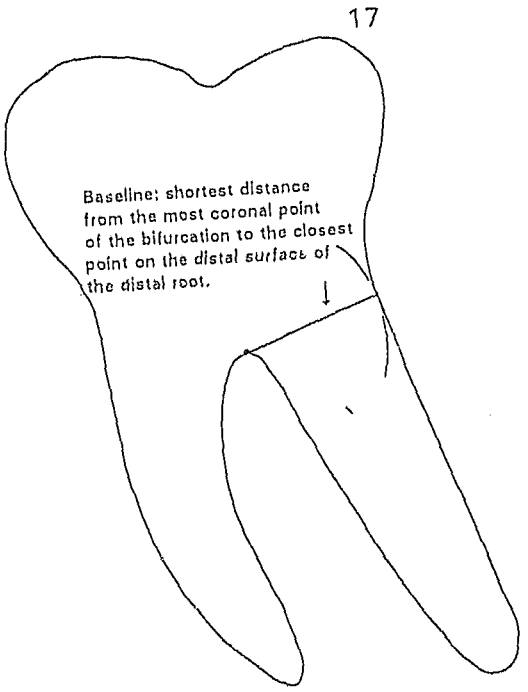


Figure 3.5

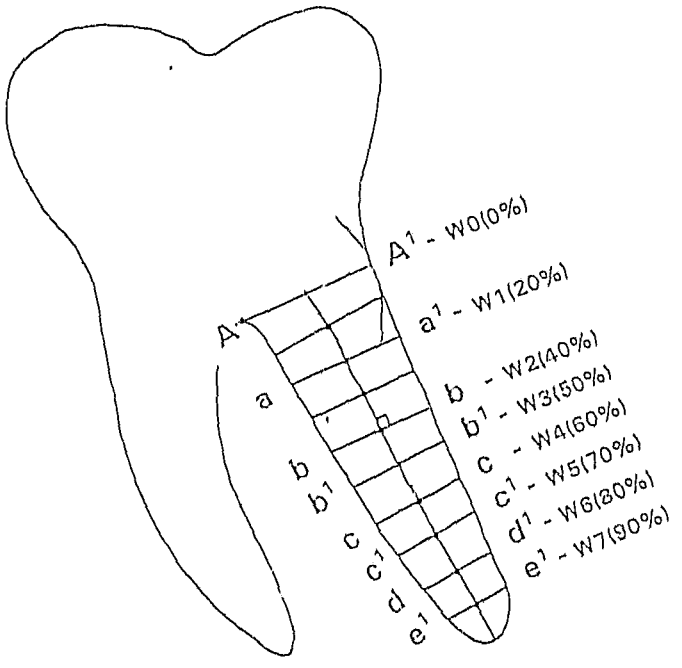


Figure 3.6

Figures 3.5 and 3.6 METHOD OF MARKING MOLAR TRACINGS FOR MEASURING.

"ORIGINAL" LEVELS AND "NEW" LEVELS

The 20%,40%, 60% and 80% levels are the same as those of Marnewick[16] (see page 7) and to these "original levels", three "new" levels at 50%, 70% and 90% were added. The set comprising the latter three levels together with the 20% and 80% levels will hereafter be referred to as the "new" levels.

MEASUREMENTS

Each tracing was placed on a two-dimensional coördinate tablet, and all measurements were done with a computerized image-analyser*.The measurements together with tooth number, age, gender and race were recorded as shown in fig.3.7.

W0 (A...A^1) = 0% (BASELINE)	.....mm
W1 (a...a^1) = 20% FROM BASELINE TO APEX	.....mm
W2 (b...b) = 40% "	.....mm
W3 (b...b^1) = 50% "	.....mm
W4 (c...c) = 60% "	.....mm
W5 (c^1...c^1) = 70% "	.....mm
W6 (d...d^1) = 80% "	.....mm
W7 (e^1...e^1) = 90% "	.....mm
L = LENGTH OF ROOT	.....mm
TOOTH NUMBER	.....
AGE	.....yrs
GENDER	m/f
RACE	.....

Figure 3.7 FORMAT FOR RECORDING MEASUREMENTS

*Videoplan, Kontron, Germany

The 10% and 30% levels in the more coronal part of the root were omitted and 50%,70%,90% levels in the apical half of the root were added because the earlier study (Marnewick 1993[16]) showed that the more apical part of the root tapers more sharply than the coronal part.

The measurements of two randomly chosen teeth (*control* molars number 7 and 12) were taken on ten separate occasions, to determine the variability of measurements (the variability was 0.26mm indicating a high degree of accuracy when taking measurements).

All measurements were then analysed as described below in order to question:

(a) whether the degree of taper differs between *experimental* and *control* subjects.

(b) whether the degree of taper is ascribable to the entire root or only to the more apical part.

(c) whether the taper of teeth is related in any way to gender and race.

(d) whether molars or premolars would be better predictors of disease; and whether the "new" levels would be better predictors of disease than the "original" levels (see pages18 and 20 for explanation of "new" and "original" levels).

Statistical analysis

INTRODUCTION

The measurements of each tracing were divided into two groups (fig. 4.1) : Group 1 comprised the baseline and the four "original" levels, (Marnewick[16], see page 7) and group 2 comprised the baseline and the five "new" levels (see page 18).

Group 1 - "original" levels	Group 2 - "new" levels
W0 (A...A^1) = 0% (BASELINE)	W0 (A...A^1) = 0% (BASELINE)
W1 (a...a^1) = 20%	W1 (a...a^1) = 20%
W2 (b...b) = 40%	W3 (b..,b^1) = 50%
W4 (c...c) = 60%	W5 (c^1...c^1) = 70%
W6 (d,..d^1) = 80%	W6 (d,..d^1) = 80%
	W7 (e^1...e^1) = 90%

Figure 4.1 "ORIGINAL" LEVELS AND "NEW" LEVELS

The "new" levels (group 2) were chosen with more measurements in the apical half of the root, which is known to taper more sharply than the coronal half (page 19), to determine whether they would perform better than the "original" levels in terms of prediction of disease.

The measurements W1, W2, W3, W4, W5, W6, W7, were then each divided by the baseline measurement W0, to yield a series of proportion-values.

The length of the root was likewise divided by the length of the baseline W0 giving a value which defined the shape of the root with lower values indicating a shorter root.

ANALYSIS

Terminology and outcome-measurements

In the case of "original" levels, there were four widths measured in addition to the baseline which had a relative width of 1. The relative widths were arbitrarily denoted u_0, u_2, u_3, u_4, u_6, where $W0/W0 = u_0 \equiv 1$ (fig.4.2).

GROUP 1	
W0 - $W0/W0 = u_0 \equiv 1$	0% (BASELINE)
W1 - $W1/W0 = u_2$	20%
W2 - $W2/W0 = u_3$	40%
W4 - $W4/W0 = u_4$	60%
W6 - $W6/W0 = u_6$	80%

Figure 4.2 RELATIVE WIDTHS OF "ORIGINAL" LEVELS

In the case of the "new" levels the relative widths were arbitrarily denoted v_0, v_1, v_2, v_3, v_4, v_5, where $v_0 \equiv 1$ (fig4.3).

GROUP 2	
W0 - W0/W0 $= v_0 \equiv 1$	0%
W1 - W1/W0 $= v_1$	20%
W3 - W3/W0 $= v_2$	50%
W5 - W5/W0 $= v_3$	70%
W6 - W6/W0 $= v_4$	80%
W7 - W7/W0 $= v_5$	90%

Figure 4.3 RELATIVE WIDTHS OF "NEW" LEVELS

The measurements can be considered in two ways, leading to two different approaches applicable both the "original" and to the "new" levels:

- The "original" or the "new" levels can be viewed as a set of multivariate observations on each root, and a test was carried out to see whether the mean of this "vector" of measurements differed between *control* and *experimental* teeth using MANOVA (Multivariate Analysis of Variance).

  In addition separate univariate tests were carried out to see whether there was any difference between *control* teeth and *experimental* teeth for the means of each "original" level. This approach was used in Marnewick's[16] study.

- The "original" or the "new" levels can be viewed as a longitudinal or 'repeated measures' set of observations along the length of the root. For groups 1 and 2 ("original" levels and "new" levels), trends were calculated to estimate the change of relative width along the length of each root. The trends could then be seen as utilising the 'response feature' approach to the analysis of repeated measures data[21].This was done by fitting regressions of width on position, separately for each tooth. In each case quadratic models were fitted and this led to the following summary measurements for each tooth :

  ub0 intercept for "original" levels
  ub1 linear effect for "original" levels (slope)
  ub2 quadratic effect for "original" levels (curvature)

  vb0 intercept for "new" levels
  vb1 linear effect for "new" levels
  vb2 quadratic effect for "new" levels

Comparison of *control* and *experimental* teeth

The mean values of the observations were calculated and tabulated by *experimental* and *control* teeth and by gender and race (sociodemographic variables) for molars and for premolars.

FORMAL STATISTICAL ANALYSIS

To test the differences between the measurements, the following analyses were carried out separately for molars and for premolars, and separately for the "original" levels and for the "new" levels.

- a multivariate analysis of variance on the relative widths - the statistical test for this analysis is Hotelling's T^2 in the case of comparisons involving factors with two levels (e.g. tooth type - *experimental* and *control*).
- a univariate analysis of variance of the relative widths of the "original" levels.
- general linear models to analyse the co-efficients of the fitted quadratics (i.e. quadratics fitted "per tooth"). In each case differences between *control* and *experimental* teeth were examined. Separate models were used adjusting for the following covariates:
  - (i) Relative root length , age, gender and race (complicated model).*
  - (ii) Relative root length and race (intermediate model).
  - (iii) Relative root length only (simple model).

  The results are discussed with reference to the SAS output.
- 'prediction' analysis[20].

The "original" and "new" levels were used to try to predict

*Note: While fitting the models it was found that there was no evidence of age and gender effects, therefore these terms were both omitted in model (ii).

the presence or absence of disease using logistic discriminant analysis separately for the premolars and for the molars. This could establish which of the groups of levels ("original" or "new") are better predictors of disease.

The principle used is as follows:

a linear discriminant function of the form

$$lp = const + b_2u_2 + b_3u_3 + b_4u_4 + b_5u_5$$

as formed by performing a logistic regression of disease status (present or absent) on the relative widths u_2, u_3, u_4, and u_5; or v_1, v_2, v_3, v_4 and v_5 in the case of the "new" levels.

This enables the probability of disease to be predicted as

$$p = \frac{\exp(lp)}{1 + \exp(lp)}$$

and then various cut off points can be used to predict whether or not a particular subject is diseased e.g. in this study 50% representing a strict criterion, and 40% a less strict criterion were used. Therefore a subject can be classified as being diseased if $p \geq 50$ (50% cut off); or $p \geq 0.40$ (40% cut off).

RESULTS

Question (a) (page 19)

In answering question (a), *whether the degrees of taper between experimental and control subjects differ*, the following results came to light:

"ORIGINAL" LEVELS

Molars:

From the summary of "original" levels, values and response features by *control* and *experimental* groups for molars (Appendix Table 1 - page 47) the following is observed:

The relative widths are smaller in *experimental* molars than in *control* molars. For the calculated (fitted) quadratic regression, the constant (ub0) and the quadratic terms are similar, while the linear term is more negative for *experimental* molars, indicating that the rate of taper is greater in *experimental* molars.

Using the model in Appendix Table 6(C) (page 56) (the MANOVA approach) for molars using "original" levels there is strong evidence that *experimental* molars taper more than *control* molars (Wilk's Lambda=0.703, P=0.0151). From Appendix Table 7(C) (page 61) there is very strong evidence (P=0.0010) that the linear trend differs between *experimental* molars and *control* molars, with *experimental* molars (ub1=-0.0653) having a sharper degree of

taper than *control* molars (ub1 = -0.0533).

"ORIGINAL" LEVELS

Premolars:

From the summary of "original" levels, values and response features by *control* and *experimental* groups for premolars (Appendix Table 1 - page 47), the following is observed:

The relative widths are smaller in *experimental* premolars than in *control* premolars. In passing, the differences in widths are greater in premolars than in molars. For the calculated contrasts, the linear contrast again shows a greater taper for *experimental* premolars.

It can be concluded fron. Appendix Table 8(C) (page 66) that there is overwhelming evidence that *experimental* are narrower than *control* premolars (Wilk's Lambda=0.5270, P=0.0002). In Appendix Table 9(C) (page 71) there is overwhelming evidence of a difference between *experimental* and *control* premolars for ub1(P=0.0002), and strong evidence for ub0 and ub2 (P=0.0111 and P=0.0185 respectively). From the mean values of the parameters (adjusted for root length) the degree of taper is significantly sharper in *experimental* premolars (ub1=-0.0675) than in the *control* premolars (ub1=-0.0512).

"NEW" LEVELS

Molars:

From the summary of "new" levels values and response features by

control and *experimental* teeth of molars the following is observed (Appendix Table 2 - page 47) :

The relative widths are smaller in *experimental* molars than in *control* molars. For the fitted quadratic regressions, the difference in coefficients is relatively small, while the linear term is more negative for *experimental* molars, indicating that the rate of taper is greater in *experimental* molars.

Appendix Table 10(C) (page 76) shows that, adjusting for relative length, there is strong evidence that the widths differ with *experimenta*l molars being narrower than *control* molars (Wilk's Lambda=0.672, P=0.0179). Appendix Table 11 (page 78) gives the results for molars using "new" levels and fitted quadratic response functions (i.e. the coefficients vb0, vb1 and vb2). Appendix Table 11(C) (page 81) shows that there is very strong evidence (P=0.0011) that the linear taper vb1 differs between *experimental* and *control* molars with the *experimental* molars (vb1=-0.06891) having a sharper mean taper than the *control* molars (vb1=-0.05724).

"NEW" LEVELS

Premolars:

From the summary of "new" levels values and response features by *control* and *experimental* groups of premolars the following is observed (Appendix Table 2 - page 47):

The relative widths are again smaller in *experimental* than in *control*

premolars (the effect being more marked than in molars). For the fitted quadratic the constant term is smaller in *experimental* premolars than in *control* premolars, showing that *experimental* premolars have a smaller average width; and the linear term is more negative for *experimental* premolars than for *control* premolars, showing that the *experimental* premolars taper more sharply.

In Appendix Table 12 (page 82) the results are given for premolars using the "new" levels. In Appendix Table 12(C) (page 86) there is overwhelming evidence (Wilk's Lambda = 0.451, P = 0.0001) that the mean widths are different for *experimental* and *control* premolars, with *experimental* premolars showing a greater degree of taper. Appendix Table 13 (page 88) gives the results for the analysis of the fitted response features i.e. vb0, vb1,and vb2 for premolars using "new" levels. From Appendix Table 13(C) (page 91) there is strong evidence that the mean vb0 and vb2 values differ for the *experimental* and *control* teeth for premolars (P = 0.0118 and P = 0.0329 respectively) and overwhelming evidence that the mean linear trend vb1 differs between *experimental* and *control* premolars (P = 0.0001) with the *experimental* premolars (mean vb1 = -0.0709) showing a greater degree of taper than the *control* premolars (mean vb1 = -0.0540).

Question (b) (page 19)

In answering question (b), *whether the degree of taper is ascribable*

to the entire root or only to the more apical part, the MANOVA approach was used. If this was significant, and only some of the univariate ANOVA figures significant then the effect is not true for the whole length of the root, but more ascribed to those parts where the univariate ANOVA figures are significant. The following came to light:

"ORIGINAL" LEVELS

Molars:

From Appendix Table 1 (page 47) the degree of taper is more marked at u_4 and u_5 than at u_2 and u_3.

Appendix Table 6(C) (page 56) shows the statistical analysis. Overall there is a significant difference in widths between *experimental* and *control* molars (Wilk's Lambda = 0.703, P = 0.0151). However in the univariate analysis u_4 and u_5 are significantly different between *experimental* and *control* molars, while u_2 and u_3 are not significantly different. Therefore the overall difference of taper between *experimental* and *control* molars is mainly due to u_4 and u_5. This shows that in molars the greater degree of taper is ascribable to the more apical part of the root in the *experimental* molars.

"ORIGINAL" LEVELS

Premolars:

From Appendix Table 1 (page 47) the degree of taper is more

uniform throughout the length of the root.

Appendix Table 8(C) (page 66) shows the statistical analysis. Overall there is a significant difference between *experimental* and *control* premolars (Wilks Lambda=0.5270, P=0.0002). In the univariate analysis there is a significant difference for u_2, u_3, u_4, and u_5 between *experimental* and *control* premolars. This shows that in premolars the degree of taper is ascribable to the entire root rather than to a particular part in the *experimental* premolars.

"NEW" LEVELS

Molars:

From Appendix Table 2 (page 47) the degree of taper is more marked at v_2,v_3, v_4 and v_5 compared to v_1.

Appendix Table 10(C) (page 76) shows the statistical analysis. Overall there is a significant difference between the widths of the *experimental* and the *control* molars (Wilks Lambda=0.672, P=0.0179). The univariate analyses show that v_2, v_3, v_4, and v_5 are significantly different between *experimental* and *control* molars while v_1 shows no significant difference. The difference in degree of taper between *experimental* and *control* molars is therefore more marked at the apex of *experimental* molars.

"NEW" LEVELS

Premolars:

From Appendix Table 2 (page 47) the difference in relative widths of the *experimental* and *control* premolars is marked at v_1, v_2, v_3, v_4, and v_5.

Appendix Table 12(C) (page 86) shows the statistical analysis revealing overwhelming evidence that the mean widths are different for *experimental* and *control* premolars, with *experimental* premolars showing a greater degree of taper throughout their lengths (Wilk's Lambda = 0.451, P = 0.0001).

The univariate analyses and adjusted means show that the differences in widths are present at all the levels, i.e. the mean values of v_1, v_2, v_3, v_4, and v_5 all differ significantly between the *experimental* and *control* premolars, supporting a marked uniform degree of taper for the *experimental* premolars.

Question (c) (page 19)

To answer the question (c) *whether the tapering of teeth is related in any way to gender or to race*, a hierarchical sequence of statistical models was fitted. The most complicated included relative length, gender, age, race and *experimental* and *control* teeth as effects; an intermediate model included relative length, race and *experimental* and *control* teeth; and the simplest included only

relative length and *experimental* and *control* teeth. If both race and gender are important, then the most complicated model should fit better than the intermediate model, as measured by the F values. Similarly if race is important then the intermediate model should fit better than the simplest model. Using two approaches, namely MANOVA and summary statistics after making observations (Appendix Table 4 - pages 49 and 50 and Appendix Table 5 - page 51), the following came to light :

"ORIGINAL" LEVELS

Molars:

From Appendix Table 4(A) (page 49) for Blacks and for Whites there are only small differences between *experimental* and *control* molars. However there is a difference between the teeth of Blacks and of Whites : all the widths for Blacks are smaller than those for Whites, and in fact the widths of *control* molars of Blacks are narrower than those of *experimental* molars of Whites at most levels. Therefore there is a potential for a confounding effect of race with *experimental* and *control* molars. This is compounded by the fact that only two out of fifteen teeth of Blacks were *control* molars, while fourteen of twenty one teeth of Whites were *control* molars (Appendix Table 3(A) - page 48). From Appendix Table 5(A) (page 51) the difference between *experimental* and *control* molars for females is less marked than that for males.

From the statistical analysis (Appendix Table 6(A) - page 52) there

is no evidence of any difference in widths attributable to gender (P=0.705). Appendix Table 6(B) (page 54) shows that there is some evidence of a race effect (P=0.0744). However if race is included in the model i.e. the intermediate model (page 24) is adopted in preference to the simplest model, the difference between *experimental* and *control* molars is no longer significant. This is due to the confounding effect between race and *experimental* and *control* molars, i.e. because of the fact that most of the molars in the *experimental* group are from Blacks, it cannot be determined from the data whether increased degree of tapering is related to being black, or to having early-onset periodontitis.

From the statistical analysis (Appendix Table 7(A) - page 58) there is no evidence of a gender effect (P=0.1921). From the statistical analysis (Appendix Table 7(B) - page 60) there is some evidence of a race effect on parameter ub1 (P=0.0644). There is no evidence of a race effect on ub0 and ub2. From Appendix Table 7(C) (page 61), if the race effect is regarded as spurious, the linear trend for *experimental* molars (ub=-0.0653) shows strong evidence (P=0.0010) of a sharper degree of taper than that of *control* molars (ub=-0.0533).

"ORIGINAL" LEVELS

Premolars:

From Appendix Table 4(A) (page 49) for Blacks and for Whites there are differences in widths between *experimental* and *control*

premolars. The widths for Blacks are smaller than those for Whites at most levels. From Appendix Table 5(A) (page 51) there is no obvious difference between males and females for *experimental* and *control* premolars.

From the statistical analysis (Appendix Table 8(A) - page 62) there is no evidence of any difference in widths attributable to gender (P=0.923). Appendix Table 8(B) (page 64) shows that there is no evidence of a race effect (P=0.6124). From the statistical analysis (Appendix Table 9(A) - page 68) there is no evidence of a gender effect (P=0.6767). From the statistical analysis (Appendix Table 9(B) - page 70) of parameters ub0,ub1,ub2 there is no evidence of a race effect (P=0.9667;0.0807;0.9526 respectively).

Overall for premolars the tapering of teeth is related neither to gender nor to race.

"NEW" LEVELS.

Molars:

From Appendix Table 4(B) (page 50) for Blacks and for Whites there is some difference between *experimental* and *control* molars. However there is a difference between the teeth of Blacks and of Whites : all the widths for Blacks are smaller than those for Whites, and in fact the widths of *control* molars of Blacks are narrower than those of *experimental* molars of Whites at most levels. Note, however, that only two out of fifteen teeth of Blacks were *control*

molars, while fourteen out of twenty one teeth of Whites were *control* molars (Appendix Table 3(A) - page 48).

From the statistical analysis (Appendix Table 10(A) - page 72) there is no evidence of any difference in widths attributable to gender (P=0.479). Appendix Table 10(B) (page 74) shows that there is some evidence of a race effect (P=0.0068). From the statistical analysis (Appendix Table 11(A) - page 78) there is no evidence of a gender effect (P=0.3357). From the statistical analysis (Appendix Table 11(B) - page 80) there is evidence of a race effect on parameter vb1 (P=0.0387). There is no evidence of a race effect on vb0 and vb2 (P=0.2901and P=0.2359 respectively).

As in the case of the "original" levels the interpretation is made difficult by the potential confounding between race and *experimental* and *control* molars. This will be considered further in the discussion.

"NEW" LEVELS

Premolars:

From Appendix Table 4(B) (page 50) for Blacks and for Whites there is a difference in widths between *experimental* and *control* premolars. The widths for Blacks are smaller than those for Whites. From Appendix Table 5(B) (page 51) there are differences in widths between *experimental* and *control* premolars for males and for females. However there are no obvious differences in widths

between males and females.

From the statistical analysis (Appendix Table 12(A) - page 82) there is no evidence of any difference in widths attributable to gender (P=0.843). Appendix Table 12(B) (page 84) shows that there is no evidence of a race effect (P=0.4198). From the statistical analysis (Appendix Table 13(A) - page 88) there is no evidence of a gender effect (P=0.8416). From the statistical analysis Appendix Table 13(B) (page 90), (parameters vb0,vb1,vb2) there is no evidence of a race effect (P=0.7985,0.0882 and 0.6216 respectively).
Thus for premolars using the "new" levels there is no evidence that width is related to gender or to race.

Question (d) (page 19)

In answering question (d), *whether molars or premolars would be better predictors of disease and whether the "new"levels would be better predictors of disease than the "original" levels* (page 20), the following came to light:

"ORIGINAL" LEVELS

Molars:

From Appendix Table 14(A) (page 92) , individually the variables do not appear significant (Wald Statistic values). However, overall the model is significant: i.e. being an *experimental* or *control* molars is related to the values of u_2, u_3, u_4 and u_5 . Using the 50%

prediction point, fourteen of the twenty *experimental* molars are correctly identified (sensitivity = 70%), and seventeen of the *control* molars are correctly identified (specificity = 85%). Sensitivity is more important than specificity[22] since the concern is to correctly identify *experimental* molars. Changing the prediction point to 40% does not increase the sensitivity from 70% and the specificity drops to 65%.

"ORIGINAL" LEVELS

Premolars:

Appendix Table 14(B) (page 93) shows the statistical results. Here the overall deviance of 22.536 on 4d.f. is highly significant (P = 0.0002) showing overwhelming evidence that *experimental* or *control* premolars are related to the values of u_2, u_3, u_4 and u_5. Here sixteen out of twenty *experimental* premolars (sensitivity = 80%) are correctly predicted at the 50% cut off point, showing that the premolars are better predictors of disease than the molars (sensitivity = 80% vs sensitivity = 70%). Reducing the cut off value to forty percent (40%) fails to improve the sensitivity above eighty percent (80%).

"NEW" LEVELS

Molars:

Appendix Table 14(C) (page 94) gives the statistical results. The overall model deviance of 14.243 on 5d.f. is significant (P = 0.014) showing strong evidence that *control* and *experimental* molars are related to the values of v_1, v_2, v_3, v_4, and v_5. Prediction of disease is

prediction point, fourteen of the twenty *experimental* molars are correctly identified (sensitivity = 70%), and seventeen of the *control* molars are correctly identified (specificity = 85%). Sensitivity is more important than specificity[22] since the concern is to correctly identify *experimental* molars. Changing the prediction point to 40% does not increase the sensitivity from 70% and the specificity drops to 65%.

"ORIGINAL"LEVELS

Premolars:

Appendix Table 14(B) (page 93) shows the statistical results. Here the overall deviance of 22.566 on 4d.f. is highly significant (P = 0.0002) showing overwhelming evidence that *experimental* or *control* premolars are related to the values of u_2, u_3, u_4 and u_5. Here sixteen out of twenty *experimental* premolars (sensitivity = 80%) are correctly predicted at the 50% cut off point, showing that the premolars are better predictors of disease than the molars (sensitivity = 80% vs sensitivity = 70%). Reducing the cut off value to forty percent (40%) fails to improve the sensitivity above eighty percent (80%).

"NEW" LEVELS

Molars:

Appendix Table 14(C) (page 94) gives the statistical results. The overall model deviance of 14.243 on 5d.f. is significant (P = 0.014) showing strong evidence that *control* and *experimental* molars are related to the values of v_1, v_2, v_3, v_4, and v_5. Prediction of disease is

slightly better for the "new"levels than for the "original"levels with a sensitivity of 75% (vs 70% for the "original"levels) and a specificity of 80% (vs 85% for the "original" levels). Decreasing the cut off point to 40% increases the sensitivity to 80%: so sensitivity is better but specificity is worse - however as discussed sensitivity is more important.

"NEW" LEVELS

Premolars:

Appendix Table 14(D) (page 95) gives the statistical results. The overall model deviance of 26.185 on 5d.f. is highly significant (P=0.0001), showing overwhelming evidence that *experimental* or *control* premolars are related to the values of v_1, v_2, v_3, v_4 and v_5. Prediction of disease here is very good with a sensitivity of 85% and a specificity of 80%. Decreasing the cut off point to 40%, increases the sensitivity to 90% i.e. eighteen out of twenty of the experimental teeth are correctly identified.

To summarize then:

1. Prediction of disease is better using premolars than molars. This concurs with previous findings in respect of question (a) where the difference in the degree of taper between *experimental* and *control* teeth was seen to be more marked for premolars than for molars (pages 26-29).
2. For premolars and for molars, the "new" levels proved to be better predictors of disease.

DISCUSSION

The problem of prediction of periodontal diseases in individuals who do not show any of the classical signs and symptoms is something which is attracting a lot of attention from researchers. From time to time a variety of measurable variables have been proposed as possible predictors of periodontal disease. These have included particular members of the bacterial flora, constituents of the gingival crevicular fluid, white cell migration rate from the gingival crevice, and genetic markers. The better known of these have turned out to be unreliable while the newer 'predictors' like genetic markers, are still unproven or are not generally available.

The simple clinical observation of peculiarly tapering roots in a number of subjects with early-onset periodontitis gave rise to the idea that a measurable morphological characteristic of the roots of teeth, observable radiographically long before the onset of disease, might turn out to be a predictor of, and an aid to diagnosing early-onset periodontitis.

A previous study by Marnewick[16] strongly suggested that a relation between the morphological characteristics of sharply tapering roots and early-onset periodontitis may exist. In this study Marnewick's work[16] has been expanded using different teeth and somewhat different methods, and the results have been subjected to extensive statistical analysis.

A pertinent difficulty relating to this research is the obscurity of any link between an apparently purely morphological variation and a classically inflammatory disease. Nevertheless, the statistical evidence linking increased degree of taper of tooth roots to early-onset periodontitis is very convincing.

A number of aims were formulated for this study, and in order to satisfy them, four questions were posed, analysed and answered separately. In answering these questions,"original" levels and "new" levels (pages 18 and 20) for mandibular first molars and maxillary second premolars were considered separately.

Question (a) was *whether the degree of taper differs between experimental and control subjects.* All observations and statistical analyses showed strong evidence that *experimental* teeth taper more sharply than *control* teeth; this was seen to be more marked for premolars than for molars. This parallels Marnewick's findings[16] of a clear and statistically highly significantly greater degree of taper of upper central incisors and lower first premolars affected with early-onset periodontitis, as compared with teeth of age matched patients with healthy periodontia.

Question (b) was *whether the degree of taper is ascribable to the entire root or only to the more apical part of the root.* For mandibular first molars the observations and statistical analyses showed that the degree of taper is more marked in the apical half of the distal

roots of the *experimental* molars. For maxillary second premolars on the other hand, the observations and statistical analyses showed that the increased degree of taper for the *experimental* premolars was ascribable to the entire root rather than to a particular part.

Question (c) sought to determine *whether the tapering of teeth is related in any way to gender or to race.* For mandibular first molars observations and statistical analyses regarding race showed that for blacks and for whites there are only small differences between *experimental* and *control* teeth. However an interesting point is that there is a difference between the molars of blacks and of whites, i.e. there is a race effect. All the widths for blacks are smaller than those for whites, and in fact the widths of *control* molars of blacks are narrower than those of *experimental* molars of whites at most levels.

It should be noted however, that only two out of fifteen molars of blacks were *control* molars, while fourteen of twenty one molars of whites were *control* teeth.

In the light of the demonstrated race effect, there is a potential for confounding effects of race with *experimental* and *control* molars. This means that if the race effect is real the difference in taper between *experimental* and *control* molars may not be significant.

It is, however, unfortunate to have had such an imbalance in numbers of *control* and *experimental* molars of black and white subjects, as the reality of the potential confounding effect cannot be determined.

It should be borne in mind that when this study was started it was not anticipated that any statistically significant difference would be found between the teeth of the black subjects and those of the white subjects.

Perhaps this was an error of judgement in that there are many craniometric and dentometric differences between blacks and whites[23, 24, 25] and in seeking a measurable criterion to serve as a predictor of a disease or as an aid to diagnosis of that disease, parameters *specific to that racial group* should be used.

It is therefore a spurious argument (as immediately above) that a racial effect for molars as revealed in answering question (c) would obviate the significance of the greater taper of *experimental* molars as determined in answering question (a).

A further study should be undertaken using two separate groups, one of Whites only and one of Blacks only, to determine the answers to questions (a), (b), (c) (gender only) and (d) separately, in strict terms of "black" parameters and "white" parameters since the predictive and diagnostic powers of these parameters would be

applied to individual white or black patients.

For mandibular first molars, observations and statistical analyses showed that there is no relationship of the tapering of teeth to gender.

However for the maxillary second premolars, observations and statistical analyses show that the increased tapering of *experimental* teeth is related neither to race nor to gender. This strengthens the validity of the maxillary second premolar as an indicator of early-onset periodontitis and as a predictor of susceptibility to the disease.

Question (d) was *whether molars or premolars would be better predictors of disease; and whether the "new" levels would be better predictors of disease than the "original" levels* (pages 18 and 20). Statistical analyses showed that prediction of disease is better with maxillary second premolars than with mandibular first molars; and that the "new" levels are better than the "original" ones.

In the light of all the above results there is no question that those maxillary second premolars which have a demonstrably increased degree of taper of their roots appear to be reliable predictors or indicators of early-onset periodontitis. The same cannot be unequivocally said of mandibular first molars because of the weaker statistical evidence of an increased degree of taper of *experimental* as apposed to *control* teeth.

CONCLUSION

The degrees of taper of maxillary second premolars and mandibular first molars of patients with early-onset periodontitis, are significantly greater than the degrees of taper of the corresponding teeth of age-matched patients with healthy periodontal tissues. The difference in the degree of taper is more marked for premolars than for molars.

The increased degree of taper is ascribable to the apical half of the root in the case of the mandibular first molars and to the entire root in the case of the maxillary second premolars.

Increased degree of taper for mandibular first molars was not related to gender. For mandibular first molars parameters derived from separate racial groups would be preferable to parameters derived from racially mixed groups. However in the case of the maxillary second premolars, increased degree of taper of *experimental* teeth is related neither to race nor to gender.

Statistically there is a stronger relationship between the degree of taper of the teeth of both types (molars and premolars) and the presence or absence of early-onset periodontitis when using measurements at the "new"levels weighted for the more apical part of the root, as opposed to the "original" levels.

One of the objectives of this study was to broaden the baseline of reference of teeth in subjects with early-onset periodontitis having demonstrably greater degrees of taper, than the corresponding teeth of periodontally healthy subjects. Putting together the findings of Marnewick[16] with the present work, all four teeth so far studied have been shown to be good indicators or predictors of early-onset periodontitis but the tapered mandibular first premolars (Marnewick[16]) and maxillary second premolars (present study) more convincingly so.

APPENDICES

APPENDIX TABLE 1 ; SUMMARY OF MEAN "ORIGINAL" LEVEL VALUES AND RESPONSE FEATURES BY *EXPERIMENTAL* AND *CONTROL* GROUPS MOLARS AND PREMOLARS

	Molar	Molar	Premolar	Premolar
Parameter	*Control*	*Experimental*	*Control*	*Experimental*
u_0	1	1	1	1
u_2	0.73	0.69	0.83	0.74
u_3	0.66	0.60	0.74	0.62
u_4	0.61	0.53	0.68	0.55
u_5	0.53	0.43	0.56	0.43
ub0	0.86	0.85	0.95	0.89
ub1	-0.05	-0.07	-0.05	-0.07
ub2	0.01	0.01	0.00	0.01

APPENDIX TABLE 2 ; SUMMARY OF MEAN "NEW" LEVEL VALUES AND RESPONSE FEATURES BY *EXPERIMENTAL* AND *CONTROL* GROUPS MOLARS AND PREMOLARS

Parameter	Molar	Molar	Premolar	Premolar
	Control	*Experimental*	*Control*	*Experimental*
v_0	1	1	1	1
v_1	0.73	0.69	0.83	0.74
v_2	0.65	0.56	0.71	0.59
v_3	0.58	0.49	0.62	0.50
v_4	0.52	0.43	0.56	0.43
v_5	0.42	0.34	0.46	0.32
vb0	0.91	0.89	0.98	0.93
vb1	-0.06	-0.07	-0.05	-0.07
vb2	0.00	0.00	-0.00	0.00

APPENDIX TABLE 3 : RELATIONSHIP OF *EXPERIMENTAL* AND *CONTROL* GROUPS MOLARS AND PREMOLARS TO SOCIODEMOGRAPHIC VARIABLES

3(A)*Control* and *Experimental* groups by race

Molars

	Black	White	Indian	Mullato	Total
Control	2	14	4	0	20
Experimental	13	7	0	0	20

Premolars

	Black	White	Indian	Mullato	Total
Control	3	16	0	1	20
Experimental	13	7	0	0	20

3(B)*Control* and *Experimental* groups by gender

Molars

	Male	Female	Total
Control	11	9	20
Experimental	9	11	20

Premolars

	Male	Female	Total
Control	11	9	20
Experimental	13	7	20

3(C) Age distribution summarised by *Control* and *Experimental* groups

Molars

	Age			
	Mean	Standard Deviation	Minimum	Maximum
Control	28.75	4.64	22	35
Experimental	28.85	6.80	16	35

For Ho : means are equal, T = 0.05 P-VAL = 0.957

Premolars

	Age			
	Mean	Standard Deviation	Minimum	Maximum
Control	28.50	6.30	13	34
Experimental	29.20	5.00	20	35

For Ho : means are equal, T = 0.40 P-VAL = 0.70

APPENDIX TABLE 4(A) MEAN "ORIGINAL" LEVEL VALUES BY *EXPERIMENTAL* AND *CONTROL* GROUPS MOLARS AND RACE

Molars

	Race							
Parameter	Black		White		Indian		Mullato	
	Control	*Experimental*	*Control*	*Experimental*	*Control*	*Experimental*	*Control*	*Experimental*
U_0	1	1	1	1	1			
U_2	0.70	0.68	0.71	0.73	0.83			
U_1	0.54	0.58	0.65	0.64	0.69			
U_4	0.59	0.60	0.60	0.57	0.66			
U_5	0.44	0.40	0.53	0.49	0.56			
Ub0	0.83	0.84	0.84	0.86	0.92			
Ub1	-0.06	-0.07	-0.05	-0.06	-0.05			
Ub2	0.01	0.01	0.01	0.01	0.00			

APPENDIX TABLE 4(A) MEAN "ORIGINAL" LEVEL VALUES BY *EXPERIMENTAL* AND *CONTROL* GROUPS PREMOLARS AND RACE

Premolars

	Race							
Parameter	Black		White		Indian		Mullato	
	Control	*Experimental*	*Control*	*Experimental*	*Control*	*Experimental*	*Control*	*Experimental*
U_0	1	1	1	1			1	
U_2	0.84	0.74	0.84	0.75			0.78	
U_3	0.72	0.2	0.75	0.63			0.66	
U_4	0.63	0.64	0.70	0.56			0.51	
U_5	0.50	0.42	0.58	0.46			0.39	
Ub0	0.97	0.09	0.95	0.89			0.94	
Ub1	-0.06	-0.07	-0.05	-0.06			-0.08	
Ub2	0.00	0.01	0.00	0.01			0.00	

APPENDIX TABLE 4(B) MEAN "NEW" LEVEL VALUES BY *EXPERIMENTAL* AND *CONTROL* GROUPS MOLARS AND RACE

Molars

	Race							
Parameter	Black		White		Indian		Mullato	
	Control	*Experi-mental*	*Control*	*Experi-mental*	*Control*	*Experi-mental*	*Control*	*Experi-mental*
V_0	1	1	1	1	1			
V_1	0.70	0.68	0.71	0.73	0.83			
V_2	0.64	0.54	0.64	0.61	0.69			
V_3	0.45	0.46	0.56	0.55	0.70			
V_4	0.44	0.40	0.53	0.49	0.56			
V_5	0.34	0.31	0.44	0.39	0.40			
Vb0	0.91	0.88	0.89	0.90	1.00			
Vb1	-0.07	-0.08	-0.06	-0.06	-0.05			
Vb2	0.00	0.01	0.00	0.00	-0.00			

APPENDIX TABLE 4(B) MEAN "NEW" LEVEL VALUES BY *CONTROL* AND *EXPERIMENTAL* GROUPS PREMOLARS AND RACE

Premolars

	Race							
Parameter	Black		White		Indian		Mullato	
	Control	*Experi-mental*	*Control*	*Experi-mental*	*Control*	*Experi-mental*	*Control*	*Experi-mental*
V_0	1	1	1	1			1	
V_1	0.84	0.74	0.84	0.75			0.78	
V_2	0.68	0.58	0.73	0.59			0.06	
V_3	0.57	0.48	0.64	0.53			0.45	
V_4	0.50	0.42	0.58	0.46			0.39	
V_5	0.41	0.32	0.48	0.32			0.30	
Vb0	0.99	0.92	0.98	0.94			0.96	
Vb1	-0.06	-0.07	-0.05	-0.07			-0.08	
Vb2	-0.00	0.00	-0.00	0.00			0.00	

APPENDIX TABLE 5(A) MEAN "ORIGINAL" LEVEL VALUES BY *CONTROL* AND *EXPERIMENTAL* GROUPS MOLARS AND PREMOLARS BY GENDER AND RACE

	Molars		Molars		Premolars		Premolars	
Parameter	Female		Male		Female		Male	
	Control	*Experimental*	*Control*	*Experimental*	*Control*	*Experimental*	*Control*	*Experimental*
U_0	1	1	1	1	1	1	1	1
U_2	0.69	0.72	0.76	0.66	0.84	0.74	0.83	0.76
U_3	0.61	0.63	0.68	0.56	0.75	0.60	0.74	0.64
U_4	0.59	0.56	0.63	0.49	0.66	0.66	0.69	0.55
U_6	0.50	0 48	0.54	0.37	0.64	0.43	0.57	0.43
Ub0	0.83	0.86	0.88	0.83	0.07	0.88	0.94	0.90
Ub1	-0.05	-0.06	-0.05	-0.07	-0.05	-0.07	-0.06	-0.07
Ub2	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01

APPENDIX TABLE 5(B) MEAN "NEW" LEVEL VALUES BY *EXPERIMENTAL* AND *CONTROL* GROUPS MOLARS AND PREMOLARS BY GENDER AND RACE

	Molars		Premolars		Molars		Premolars	
Parameter	Female		Male		Female		Male	
	Control	*Experimental*	*Control*	*Experimental*	*Control*	*Experimental*	*Control*	*Experimental*
V_0	1	1	1	1	1	1	1	1
v_1	0.69	0.72	0.76	0.66	0.84	0.74	0.83	0.77
v_2	0.62	0.59	0.67	0.53	0.71	0.57	0.71	0.57
v_3	0.52	0.53	0.63	0.44	0.60	0.51	0.64	0.47
v_4	0.50	0.48	0.54	0.37	0.54	0.43	0.57	0.43
V_6	0.40	0.39	0.43	0.28	0.44	0.34	0.47	0.31
vb0	0.88	0.89	0.94	0.88	0.19	0.92	0.97	0.94
vb1	-0.06	-0.06	-0.06	-0.07	-0.06	-0.07	-0.06	-0.07
vb2	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00

APPENDIX TABLE 6(A) SUMMARY MANOVA APPROACH FOR MOLARS USING "ORIGINAL" LEVELS

(A) Full model (relative length, age, gender, race and *control* and *experimental* groups molars and premolars.)

MANOVA

Source	d.f.	Wilk's Lambda	F-value	P-value
Relative length	1	0.651	4.02	0.0100
Gender	1	0.932	0.54	0.7053
Age	1	0.952	0.38	0.8243
Race	2	0.672	1.65	0.1303
Cont. vs *Exp.**	1	0.852	1.30	0.2932

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Discriminant function for *control* and *experimental* groups molars and premolars.

$D = -0.516u_2 - 1.681u_3 + 3.222u_4 + 0.120u_6$

Univariate ANOVA tables

Variable :u2

Source	df	Type III SS	MS	F- value	P- value
Relative length	1	0.0860	0.0860	14.07	0.0007
Gender	1	0.00258	0.00258	0.42	0.5199
Age	1	0.00156	0.00156	0.26	0.6169
Race	2	0.01847	0.0012	1.51	0.235
Cont . vs *Exp.**	1	0.00035	0.00035	0.06	0.8130
Residual	33	0.20158	0.00611		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u3

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.07211	0.07211	9.57	0.000
Gender	1	0.00307	0.00307	0.41	0. 527
Age	1	0.00077	0.00077	0.10	0.752
Race	2	0.02280	0.01140	1.51	0.235
Cont . vs *Exp.**	1	0.00159	0.00159	0.21	0.649
Residual	33	0.24872	0.00754		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u4

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.06489	0.06439	9.47	0.004
Gender	1	0.00713	0.00713	1.05	0.313
Age	1	0.00544	0.00544	0.80	0.377
Race	2	0.01540	0.00770	1.13	0.334
*Cont . vs Exp.**	1	0.02193	0.02193	3.23	0.0811
Residual	33	0.22431	0.006797		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u5

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.03914	0.03914	6.26	0.017
Gender	1	0.01384	0.01384	2.21	0.146
Age	1	0.00033	0.00033	0.05	0.820
Race	2	0.03994	0.01997	3.19	0.054
*Cont . vs Exp.**	1	0.01647	0.01647	2.63	0.114
Residual	33	0.20644	0.00626		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Adjusted means for *control* and *experimental* groups molars and premolars
(Adjusted for relative length, gender, age and race).

VARIABLE				
Group	u2	u3	u4	u5
CONTROL	0.733	0.634	0.606	0.509
EXPERIMENTAL	0.726	0.618	0.545	0.457

APPENDIX TABLE 6(B) SUMMARY OF MANOVA APPROACH FOR MOLARS USING "ORIGINAL" LEVELS

(B) Reduced model (relative length, race and *control* and *experimental* groups molars and premolars)

Source	d.f.	Wilk's Lambda	F-value	P-value
Relative length	1	0.671	3.917	0.0107
Race	2	0.572	1.905	0.0744
Cont vs *Exp.**	1	0.849	1.423	0.2489

**Cont* vs *Exp.* = *Control* vs *Experimental* groups

Discriminant function for tooth group

$D = -0.592\ u_2 - 1.993\ u_3 + 3.466\ U_4 - 0.212\ U_5$

Univariate ANOVA tables

Variable : u2

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.08528	0.08528	14.54	0.0005
Race	2	0.01721	0.00861	1.47	0.2444
Cont . vs *Exp.**	1	0.00033	0.00033	0.06	0.8127
Residual	35	0.20531	0.00587		

**Cont* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u3

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.07045	0.07045	9.77	0.0036
Race	2	0.02520	0.01260	1.75	0.1889
Cont . vs *Exp.**	1	0.00139	0.00139	0.19	0.6629
Residual	35	0.25225	0.00721		

**Cont* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u4

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.06206	0.06206	9.22	0.0045
Race	2	0.01565	0.00783	1.16	0.3245
Cont . vs *Exp.**	1	0.02289	0.02289	3.40	0.0736
Residual	35	0.23558	0.00673		

**Cont* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u5

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.03346	0.03346	5.32	0.0272
Race	2	0.048439	0.02422	3.85	0.0309
Cont . vs *Exp.**	1	0.01373	0.01373	2.18	0.1486
Residual	35	0.22031	0.00629		

**Cont* vs *Exp.* = *Control* vs *Experimental* groups

Adjusted means for *control* and *experimental* groups molars and premolars
(Adjusted for relative length and race).

VARIABLE				
Group	u2	u3	u4	u5
CONTROL	0.731	0.632	0.602	0.505
EXPERIMENTAL	0.724	0.617	0.541	0.458

APPENDIX TABLE 6(C) SUMMARY MANOVA APPROACH FOR MOLARS USING "ORIGINAL" LEVELS

(C) Minimal model (relative length and *control* and *experimental* groups)

MANOVA

Source	d.f.	Wilk's Lambda	F-value	P-value
Relative length	1	0.614	5.339	0.0019
Cont. vs *Exp.**	1	0.703	3.591	0.0151

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Discriminant function for *control* and *experimental* groups.

$D = 1.942u_2 + 1.110u_3 - 1.433u_4 + 0u_5$

Univariate ANOVA tables

Variable :u2

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.12457	0.12457	20.71	0.0001
Cont . vs *Exp.**	1	0.0.1350	0.0135	2.25	0.1425
Residual	37	0.22252	0.0060		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u3

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.08593	0.08593	11.46	0.0017
Cont . vs *Exp.**	1	0.02349	0.02349	3.13	0.0850
Residual	37	0.27745	0.00750		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u4

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.07572	0.07572	11.15	0.0019
Cont . vs *Exp.**	1	0.07633	0.07633	11.24	0.0019
Residual	37	0.25123	0.00679		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : u5

Source	df	Type III SS	MS	F- value	P>F
Relative length	1	0.04641	0.04641	6.25	0.0170
Cont . vs *Exp.**	1	0.08918	0.08918	12.28	0.0012
Residual	37	0.26874	0.00726		

**Cont* vs *Exp.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups.
(Adjusted for relative length only)

	VARIABLE			
Group	u2	u3	u4	u5
CONTROL	0.731	0.647	0.614	0.526
EXPERIMENTAL	0.694	0.599	0.526	0.431

APPENDIX TABLE 7 SUMMARY RESPONSE FEATURE APPROACH FOR MOLARS USING "ORIGINAL" LEVELS

(A) Full model (relative length, age, gender, race and *Control* vs *Experimental* groups)

Variable : ub0 (intercept from fitted quadratic)

Source	df	Type II SS	MS	F	P>F
Relative length	1	0.05278	0.05278	7.18	0.0114
Gender	1	0.000089	0.000089	0.01	0.9130
Age	1	0.00134	0.00134	0.18	0.6722
Race	2	0.00480	0.00240	0.33	0.7237
**Cont* vs *Expt*	1	0.000137	0.000137	0.02	0.8923
Residual	33	0.24258	0.00735		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : ub1 (slope from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.3173	0.3173	3.11	0.0870
Gender	1	0.1808	0.1808	1.77	0.1921
Age	1	0.0124	0.0124	0.12	0.7290
Race	2	0.4938	0.4938	2.42	0.1044
**Cont* vs *Expt*	1	0.3727	0.3727	3.66	0.0646
Residual	33	3.364			

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable :ub2 (curvature from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.1511	0.1511	5.65	0.0235
Gender	1	0.00004	0.00004	0.00	0.9704
Age	1	0.00558	0.00558	0.21	0.6508
Race	2	0.00770	0.00385	0.14	0.8665
**Cont* vs *Expt*	1	0.00003	0.00003	0.00	0.9721
Residual	33	0.88314	0.02676		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* molars
(Adjusted for relative length, gender, age and race)

Variable	*Control*	*Experimental*
ub0	0.859	0.864
ub1	-0.0554	-0.0633
ub2	0.00736	0.00728

APPENDIX TABLE 7 SUMMARY RESPONSE FEATURE APPROACH FOR MOLARS USING "ORIGINAL" LEVELS

(B) Reduced model (relative length, *race* and *Control* vs *Experimental* groups)

Variable : ub0 (fitted quadratic intercept)

Source	df	Type II SS	MS	F	P>F
Relative length	1	0.05484	0.05434	7.87	0.0082
Race	2	0.00373	0.001866	0.27	0.7667
**Cont* vs *Expt*	1	0.000052	0.000052	0.01	0.9314
Residual	35	0.24394	0.00697		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : ub1 (fitted quadratic : slope)

Source	df	Type II SS	MS	F	P>F
Relative length	1	0.000261	0.000261	2.57	0.1178
Race	2	0.000602	0.00030	2.97	0.0644
**Cont* vs *Expt*	1	0.000337	0.00337	3.33	0.0767
Residual	35	0.003548	0.000101		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : ub2 (fitted quadratic : curvature)

Source	df	Type II SS	MS	F	P>F
Relative length	1	0.000159	0.000159	6.26	0.01720.0172
Race	2	0.0000047	0.0000029	0.09	0.9117
**Cont* vs *Expt*	1	0.0000003	0.00000003	0.00	0.9722
Residual	35	0.0008887	0.0000254		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Adjusted means (Adjusted for relative length and race)

	Variable		
Group	ub0	ub1	ub2
Control	0.859	-0.056	0.0074
Experi-mental	0.862	-0.063	0.0075

APPENDIX TABLE 7 SUMMARY RESPONSE FEATURE APPROACH FOR MOLARS USING "ORIGINAL" LEVELS

(C) Minimal model (relative length and *Control* and *Experimental* groups)

Variable : ub0 (fitted quadratic : intercept)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	72.785	72.785	10.87	0.0022
**Cont* vs *Expt*	1	1.020	1.020	0.15	0.6985
Residual	37	247.67	6.694		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : ub1 (fitted quadratic : slope)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.0305	0.3035	2.71	0.1085
**Cont vs Expt*	1	1.434	1.434	12.78	0.0010
Residual	37	4.1510	0.1122		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Variable : ub2 (fitted quadratic : curvature)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.1981	0.1981	8.20	0.0068
**Cont* vs *Expt*	1	0.0033	0.0033	0.14	0.7137
Residual	37	0.8934	0.0242		

**Cont.* vs *Exp.* = *Control* vs *Experimental* groups

Adjusted means (Adjusted for relative length)

	Variable		
Group	ub0	ub1	ub2
Control	0.858	-0.0533	0.00736
Experimental	0.848	0.0653	0.00793

APPENDIX TABLE 8 SUMMARY MANOVA APPROACH FOR PREMOLARS USING "ORIGINAL" LEVELS

(A) Full model (relative length, age, gender, race and tooth group)

MANOVA

Source	d.f.	Wilk's Lambda	F	P-value
Relative length	1	0.924	0.6165	0.6541
Gender	1	0.9712	0.2226	0.9237
Age	1	0.9890	0.0835	0.9889
Race	2	0.8249	0.7580	0.6406
Cont. vs *Exp.**	1	0.6184	4.6273	0.0050

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *Control* and *Experimental* groups.

$D = 1.763u_2 - 0.173u_3 - 0.0236u_4 + 1.341u_6$

Univariate ANOVA tables

Variable : u2

Source	df	Type III SS	MS	F-value	P>F
Relative length	1	0.00034	0.00034	0.08	0.7811
Gender	1	0.00066	0.00066	0.15	0.6993
Age	1	0.00081	0.00081	0.19	0.6695
Race	2	0.003947	0.00197	0.45	0.6392
**Cont* vs *Expt*	1	0.05528	0.05528	12.71	0.0011
Residual	33	0.14364	0.00435		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : u3

Source	df	Type III SS	MS	F - value	P>F
Relative length	1	0.001076	0.001076	0.14	0.7131
Gender	1	0.000339	0.000339	0.04	0.8365
Age	1	0.001175	0.001175	0.15	0.7009
Race	2	0.008219	0.00411	0.53	0.5963
**Cont* vs *Expt*	1	0.09313	0.093131	11.90	0.0016
Residual	33	0.2582	0.00783		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : u4

Source	df	Type III SS	MS	F - value	P>F
Relative length	1	0,000987	0,000987	1,02	0,3191
Gender	1	0,00022	0,00022	0,02	0,8801
Age	1	0,000076	0,000076	0,01	0,9300
Race	2	0,032417	0,01621	1,68	0,2019
**Cont* vs *Expt*	1	0,1198	0,1198	12,42	0,0013
Residual	33	0,31832	0,009646		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : u5

Source	df	Type III SS	MS	F - value	P>F
Relative length	1	0,01814	0,01814	2,37	0,1331
Gender	1	0,000888	0,000888	0,12	0,7354
Age	1	0,000275	0,000275	0,04	0,8508
Race	2	0,04250	0,02125	2,78	0,0767
**Cont* vs *Expt*	1	0,10362	0,10362	13,55	0,0008
Residual	33	0,25245	0,007650		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups
(Adjusted for relative length, gender, age and race)

	Variable			
Group	U2	U3	U4	U5
Control	0.816	0.717	0.625	0.504
Experimental	0.725	0.598	0.491	0.379

APPENDIX TABLE 8 SUMMARY MANOVA APPROACH FOR PREMOLARS USING "ORIGINAL" LEVELS

(B) Reduced model (relative length, race and *Control* vs *Experimental* groups)

MANOVA

Source	df	Wilks Lambda	F	P - value
Relative length	1	0.9004	0.8846	0.4842
Race	2	0.8281	0.7910	0.6124
**Cont* vs *Expt*	1	0.6174	4.9585	0.0032

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *control* and *experimental* groups.

$D = +1.756u_2 - 0.2025u_3 - 0.0178u_4 + 1.3677u_6$

Univariate ANOVA tables

Variable : U2

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.000064	0.000064	0.02	0.9018
Race	2	0.003574	0.001787	0.43	0.6525
**Cont* vs *Expt*	1	0 05453	0.05453	13.19	0.0009
Residual	35	0.14473	0.00414		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : u3

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.000507	0.000507	0.07	0.795
Race	2	0.00900	0.00450	0.61	0.5515
**Cont* vs *Expt*	1	0.09190	0.09190	12.36	0.0012
Residual	35	0.2602	0.00743		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : u4

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.01082	0.01082	1.19	0.2831
Race	2	0.03387	0.01693	1.86	0.1708
**Cont* vs *Expt*	1	0.1204	0.1204	13.22	0.0009
Residual	35	0.31871	0.00911		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : u5

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.02323	0.02323	3.21	0.0819
Race	2	0.04373	0.0219	3.02	0.0617
**Cont* vs *Expt*	1	0.10574	0.10574	14.60	0.0005
Residual	35	0.2534	0.00724		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length and race)

	Variable			
Group	U2	U3	U4	U5
Control	0.817	0.716	0.624	0.503
Experimental	0.727	0.599	0.491	0.378

APPENDIX TABLE 8 SUMMARY MANOVA APPROACH FOR PREMOLARS USING "ORIGINAL" LEVELS

(C) Minimal model (relative length and *Control* vs *Experimental* groups)

MANOVA

Source	df	Wilk's Lambda	F	P - value
Relative length	1	0.8833	1.1227	0.3621
**Cont* vs *Expt*	1	0.5271	7.6283	0.0002

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *Control* and *Experimental* groups.

$D = 1.576u_2 + 0.0965u_3 - 0.3869u_4 + 1.4590u_5$

Univariate ANOVA tables

Variable : u2

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.00018	0.00018	0.04	0.8346
**Cont* vs *Expt*	1	0.07990	0.07990	19.93	0.0001
Residual	37	0.1483	0.00401		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : u3

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.00111	0.00111	0.15	0.6987
**Cont* vs *Expt*	1	0.1405	0.1405	19.32	0.0001
Residual	37	0.26916	0.00727		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : u4

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.01497	0.01497	1.57	0.2179
**Cont* vs *Expt*	1	0.18202	0.18202	19.10	0.0001
Residual	37	0.35257	0.00953		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable :u5

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.03354	0.03354	4.18	0.0482
**Cont* vs *Expt*	1	0.1869	0.1869	23.27	0.0001
Residual	37	0.29717	0.0080		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length only)

	Variable			
Group	U2	U3	U4	U5
Control	0.835	0.745	0.681	0.565
Experimental	0.744	0.624	0.543	0.425

APPENDIX TABLE 9 SUMMARY RESPONSE FEATURE APPROACH FOR PREMOLARS USING "ORIGINAL" LEVELS

(A) Full model : (relative length, age, gender, race and *control* and *experimental* groups)

Variable : ub0 (intercept from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	0.6380	0.6380	0.12	0.7329
Gender	1	0.3012	0.3012	0.06	0.8145
Age	1	1.711	1.711	0.32	0.5768
Race	2	0.7760	0.3880	0.07	0.9306
**Cont* vs *Expt*	1	28.548	28.548	5.30	0.0277
Residual	33	1.77.69	5.384		

**Cont* vs *Expt* = *Control* vs *Experimental* groups

Variable : ub1 (slope from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	0.3066	0.3066	2.16	0.1511
Gender	1	0.02512	0.02512	0.18	0.6767
Age	1	0.0070	0.0070	0.05	0.8258
Race	2	0.7002	0.3501	2.47	0.1006
**Cont* vs *Expt*	1	1.424	1.424	10.03	0.003
Residual	33	4.6854	0.1420		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : ub2 (curvature from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	0.00235	0.00235	0.11	0.7372
Gender	1	0.00030	0.00036	0.02	0.8956
Age	1	0.0061	0.0061	0.30	0.5883
Race	2	0.0034	0.0017	0.08	0.9215
**Cont* vs *Expt*	1	0.09569	0.09569	4.65	0.0383
Residual	33	0.6784			

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length, gender, age and race)

VARIABLE	*CONTROL*	*EXPERIMENTAL*
ub0	0.950	0.885
ub1	-0.0592	-0.0738
ub2	0.00238	0.00617

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length, gender, age and race)

VARIABLE	*CONTROL*	*EXPERIMENTAL*
ub0	0.950	0.885
ub1	-0.0592	-0.0738
ub2	0.00238	0.00617

APPENDIX TABLE 9 SUMMARY RESPONSE FEATURE APPROACH FOR PREMOLARS USING "ORIGINAL" LEVELS

(B) Reduced model (relative length, race and *Control* and *Experimental* groups)

Variable ; ub0 (fitted quadratic : intercept)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	1.927	1.927	0.38	0.5438
Race	2	0.3474	0.1737	0.03	0.9667
**Cont* vs *Expt*	1	27.44	27.44	5.35	0.0267
Residual	35	179.46	5.128		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : ub1 (fitted quadratic : slope)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	0.4018	0.4018	2.98	0.0929
Race	2	0.7291	0.3646	2.71	0.0807
**Cont vs Expt*	1	1.4585	1.4585	10.83	0.0023
Residual	35	4.7128	0.1346		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : ub2 (fitted quadratic : curvature)

Source	df	Type II SS ($x10^{-2}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	0.00696	0.00696	0.36	0.5545
Race	2	0.00190	0.00095	0.05	0.9526
**Cont* vs *Expt*	1	0.09177	0.09177	4.69	0.0372
Residual	35	0.6845	0.01956		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means (Adjusted for relative length and race)

	Variable		
Group	ub0	ub1	ub2
Control	0.950	-0.0593	0.00237
Experimental	0.886	-0.0740	0.00607

APPENDIX TABLE 9 SUMMARY RESPONSE FEATURE APPROACH FOR PREMOLARS USING "ORIGINAL" LEVELS

(C) Minimal model (relative length and *Control* and *Experimental* groups)

Variable : ub0 (fitted quadratic : intercept)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	2,312	2,312	0.48	0.4946
**Cont* vs *Expt*	1	34,77	34,77	7,16	0,011
Residual	37	179,81	4,860		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : ub1 (fitted quadratic : slope)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	0,5648	0,5648	3,84	0,0578
**Cont* vs *Expt*	1	2,543	2,543	17,29	0,0002
Residual	37	5,442	0,1471		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : ub2 (fitted quadratic : curvature)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F - value	P>F
Relative length	1	0,00858	0,00858	0,46	0,5006
**Cont* vs *Expt*	1	-,11265	0,11265	6,07	0,0186
Residual	37	0,6864	0,01855		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means (Adjusted for relative length)

	Variable		
Group	ub0	ub1	ub2
Control	0,952	-0,0512	0,00223
Experimental	0,892	-0,0675	0,00566

APPENDIX TABLE 10 SUMMARY MANOVA APPROACH FOR MOLARS USING "NEW" LEVELS

(A) Full model (relative length, age, gender, race and *Control and Experimental* groups)
MANOVA

Source	df	Wilk's Lambda	F - value	P - value
Relative length	1	0.640	3.2873	0.0184
Gender	1	0.862	0.9249	0.4791
Age	1	0.915	0.6368	0.7467
Race	2	0.518	2.2602	0.0261
**Cont* vs *Expt*	1	0.769	1.7426	0.1564

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *Control* and *Experimental* groups.
$D = -1.438v_1 + 3.328v_2 - 2.178v_3 + 1.294v_4 + 0.301v_5$

Univariate ANOVA tables

Variable : v1

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.0860	0.0860	14.07	0.0007
Gender	1	0.00258	0.00258	0.42	0.5199
Age	1	0.00156	0.00156	0.26	0.6169
Race	2	0.01847	0.00923	1.51	0.2355
**Cont* vs *Expt*	1	0.000347	0.000347	0.06	0.8130
Residual	33	0.20158	0.00611		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v2

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.05291	0.5291	8.38	0.0067
Gender	1	0.00356	0.00356	0.56	0.4580
Age	1	0.00961	0.00961	1.52	0.2261
Race	2	0.01520	0.00760	1.20	0.3133
**Cont* vs *Expt*	1	0.02057	0.02057	3.26	0.0802
Residual	33	0.20843	0.00632		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v3

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.0517	0.0517	6.33	0.0169
Gender	1	0.00033	0.00033	0.04	0.8420
Age	1	0.00682	0.00682	0.83	0.3675
Race	2	0.08724	0.0436	5.34	0.0098
**Cont* vs *Expt*	1	0.00233	0.00233	0.29	0.5969
Residual	33	0.26970	0.00817		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v4

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.04009	0.04009	6.47	0.0159
Gender	1	0.01353	0.01353	2.18	0.1491
Age	1	0.00043	0.00043	0.07	0.7944
Race	2	0.03988	0.01994	3.22	0.0530
**Cont* vs *Expt*	1	0.01592	0.01592	2.57	0.1186
Residual	33	0.20460	0.00620		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v5

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.04516	0.04516	5.34	0.0272
Gender	1	0.01581	0.01581	1.87	0.1808
Age	1	0.00125	0.00125	0.15	0/7035
Race	2	0.04391	0.0195	2.60	0.0898
**Cont* vs *Expt*	1	0.01714	0.01714	2.03	0.1640
Residual	33	0.27911	0.00846		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups
(Adjusted for relative length, gender, age and race)

	Variable				
Group	v1	v2	v3	v4	v5
Control	0.733	0.639	0.573	0.509	0.396
Experimental	0.726	0.581	0.553	0.457	0.343

APPENDIX TABLE 10 SUMMARY MANOVA APPROACH FOR MOLARS USING "NEW" LEVELS

(B) Reduced model (relative length, race and *Control and Experimental* groups)

MANOVA

Source	df	Wilk's Lambda	F - value	P - value
Relative length	1	0.664	3.1384	0.0209
Race	2	0.478	2.7688	0.0068
**Cont* vs *Expt*	1	0.781	1.7356	0.1558

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *Control* and *Experimental* groups.

$D = -1.794v_1 + 3.557v_2 - 1.762v_3 + 0.454v_4 + 0.556v_5$

Univariate ANOVA tables

Variable : v1

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.0853	0.0853	14.54	0.0005
Race	2	0.0172	0.00861	1.47	0.2444
**Cont* vs *Expt*	1	0.000334	0.000334	0.06	0.8127
Residual	35	0.2053	0.00587		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v2

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.05328	0.05328	8.45	0.0063
Race	2	0.01313	0.01313	1.04	0.3632
**Cont* vs *Expt*	1	0.02375	0.02375	3.77	0.0602
Residual	35	0.22039	0.00630		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v3

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.05464	0.5464	6.91	0.0126
Race	2	0.08119	0.04059	5.14	0.011
**Cont* vs *Expt*	1	0.00364	0.00364	0.46	0.5018
Residual	35	0.27659	0.00790		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v4

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.03451	0.03451	5.54	0.0244
Race	2	0.04804	0.0240	3.85	0.0307
**Cont* vs *Expt*	1	0.01336	0.0134	2.14	0.1521
Residual	35	0.21817	0.00623		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v5

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.03910	0.03910	4.63	0.0383
Race	2	0.05509	0.02754	3.26	0.0501
**Cont* vs *Expt*	1	0.01477	0.01477	1.75	0.1945
Residual	35	0.29535	0.00844		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length and race)

	Variable				
Group	v1	v2	v3	v4	v5
Control	0.731	0.636	0.571	0.504	0.391
Experi-menta/	0.724	0.575	0.547	0.458	0.342

APPENDIX TABLE 10 SUMMARY MANOVA APPROACH FOR MOLARS USING "NEW" LEVELS

(C)Minimal model (relative length and *Control and Experimental* groups)

MANOVA

Source	df	Wilk's Lambda	F - value	P - value
Relative length	1	0.605	4.3172	0.0039
*Cont vs Expt	1	0.672	3.2170	0.0179

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *Control* and *Experimental* groups.

$D = -0.461v_1 + 0.615v_2 + 0.932v_3 - 4.84v_4 + 4.097v_5$

Univariate ANOVA tables

Variable : v1

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.1246	0.1246	20.71	0.0001
*Cont vs Expt	1	0.0135	0.0135	2.25	0.1425
Residual	35	0.2225	0.00601		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v2

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.0653	0.0653	10.35	0.0027
*Cont vs Expt	1	0.0747	0.0747	11.83	0.0015
Residual	37	0.23352	0.00631		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v3

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.10659	0.10659	11.02	0.0020
*Cont vs Expt	1	0.08574	0.08574	8.87	0.0051
Residual	37	0.35778	0.00967		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v4

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.04678	0.04678	6.50	0.0151
*Cont vs Expt	1	0.08776	0.8776	12.20	0.0012
Residual	37	0.26621	0.00719		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v5

Source	df	TypeIII SS	MS	F - value	P>F
Relative length	1	0.0354	0.0354	3.74	0.0608
**Cont* vs *Expt*	1	0.0652	0.0652	6.89	0.0125
Residual	37	0.3504	0.00947		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length only)

	Variable				
Group	v1	v2	v3	v4	v5
Control	0.731	0.647	0.580	0.525	0.420
Experi-menta/	0.694	0.561	0.487	0.431	0.339

APPENDIX TABLE 11 SUMMARY RESPONSE FEATURE APPROACH FOR MOLARS USING "NEW" LEVELS

(A) Full model (relative length, age, gender, race and *Control* vs *Experimental* groups)

Variable : vb0 (intercept from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	31.817	31.817	6.32	0.0170
Gender	1	0.00153	0.00153	0.00	0.9862
Age	1	2.9775	2.9775	0.59	0.4474
Race	2	14.857	7.429	1.48	0.2435
**Cont* vs *Expt*	1	0.2370	0.2470	0.05	0.8261
Residual	33	166.1976	5.036		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb1 (slope from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.4423	0.4423	4.57	0.0399
Gender	1	0.09227	0.09227	0.95	0.3357
Age	1	0.04866	0.04866	0.50	0.4830
Race	2	0.6351	0.3176	3.28	0.0500
**Cont* vs *Expt*	1	0.2274	0.2274	2.35	0.1346
Residual	33	3.1903	0.09668		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb2 (curvature from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.006195	0.06915	3.65	0.0648
Gender	1	0.00128	0.00128	0.08	0.9852
Age	1	0.01420	0.01420	0.84	0.3671
Race	2	0.05996	0.02998	1.77	0.1869
**Cont* vs *Expt*	1	0.00177	0.0177	0.10	0.7492
Residual	33	0.56034	0.01698		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length, gender, age and race)

Variable	*Control*	*Experimental*
ub0	0.921	0.914
vb1	-0.05931	-0.06545
vb2	0.00227	0.00281

APPENDIX TABLE 11 SUMMARY RESPONSE FEATURE APPROACH FOR MOLARS USING "NEW" LEVELS

(B) Reduced model (relative length, race and *Control* vs *Experimental* groups)

Variable : vb0 (fitted quadratic : contrast)

Source	df	Type II SS	MS	F	P>F
Relative length	1	0.03427	0.03427	7.09	0.0116
Race	2	0.01240	0.00620	1.28	0.2901
*Cont vs Expt	1	0.000637	0.000637	0.13	0.7188
Residual	35	0.16923	0.004835		

*Cont vs Expt. = Control vs Experimental groups

Variable : vb1 (fitted quadratic : slope)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.4115	0.4115	4.34	0.0446
Race	2	0.6775	0.6775	3.57	0.0387
*Cont vs Expt	1	0.2303	0.2303	2.43	0.1281
Residual	35	3.3172	0.09478		

*Cont vs Expt. = Control vs Experimental groups

Variable : vb2 (fitted quadratic : curvature)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.0713	0.0713	4.32	0.0450
Race	2	0.04964	0.0248	1.51	0.2359
*Cont vs Expt	1	0.00458	0.00458	0.28	0.6013
Residual	35	0.57705	0.01649		

*Cont vs Expt. = Control vs Experimental groups

Adjusted means for *Control* and *Experimental* groups
(Adjusted for relative length and race)

Variable	*Control*	*Experimental*
vb0	0.9209	0.9109
vb1	-0.05973	-0.06578
vb2	0.00225	0.00310

APPENDIX TABLE 11 SUMMARY RESPONSE FEATURE APPROACH FOR MOLARS USING "NEW" LEVELS

(C) Minimal model (relative length and *Control* vs *Experimental* groups)

Variable : vb0 (fitted quadratic : intercept)

Source	df	Type II SS	MS	F	P>F
Relative length	1	0.05627	0.05627	11.46	0.0017
*Cont vs *Expt*	1	0.00754	0.00754	1.54	0.2231
Residual	37	0.18164	0.004910		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb1 (fitted quadratic : slope)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.5619	0.5619	5.20	0.0284
*Cont vs *Expt*	1	1.3625	1.3625	12.62	0.0011
Residual	37	3.9947	0.10796		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb2 (fitted quadratic : curvature)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.13294	0.13294	7.85	0.0080
*Cont vs *Expt*	1	0.03689	0.03689	2.18	0.1485
Residual	37	0.6267	0.01694		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups
(Adjusted for relative length)

Variable	*Control*	*Experimental*
vb0	0.9143	0.8869
vb1	-0.05724	-0.06891
vb2	0.002687	0.004608

APPENDIX TABLE 12 SUMMARY MANOVA APPROACH FOR PREMOLARS USING "NEW" LEVELS

(A) Full model (relative length, age, gender, race and *Control and Experimental* groups)

MANOVA

Source	df	Wilk's Lambda	F - value	P - value
Relative length	1	0.742	2.0188	0.1055
Gender	1	0.935	0.4012	0.8439
Age	1	0.931	0.4284	0.8251
Race	2	0.699	1.1361	0.3522
*Cont vs Expt	1	0.467	6.6192	0.0003

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *Control* and *Experimental* groups.

$D = 1.274v_1 + 0.0742v_2 - 0.5027v_3 - 1.291v_4 + 3.320v_5$

Univariate ANOVA tables

Variable : v1

Source	df	TypeIII SS	MS	F	P>F
Relative length	1	0.000348	0.000348	0.08	0.7789
Gender	1	0.000731	0.000731	0.17	0.6841
Age	1	0.000784	0.000784	0.18	0.6734
Race	2	0.0003949	0.001975	0.46	0.6381
*Cont vs Expt	1	0.05511	0.05511	12.71	0.0011
Residual	33	0.14305	0.001133		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v2

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.00402	0.00402	0.49	0.4903
Gender	1	0.000003	0.000003	0.00	0.9847
Age	1	0.003787	0.00387	0.49	0.4986
Race	2	0.01588	0.00794	0.95	0.3978
*Cont vs Expt	1	0.10880	0.10880	13.16	0.0010
Residual	33	0.27287	0.00827		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : V3

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.01050	0.01050	1.35	0.2545
Gender	1	0.00046	0.00046	0.06	0.8105
Age	1	0.00023	0.00023	0.03	0.8661
Race	2	0.04347	0.02174	2.79	0.0762
Cont vs Expt	1	0.08928	0.08928	11.44	0.0019
Residual	33	0.25749	0.00780		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : V4

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.01803	0.01802	2.36	0.1842
Gender	1	0.00077	0.00077	0.10	0.7534
Age	1	0.00029	0.00029	0.04	0.8480
Race	2	0.04205	0.02103	2.75	0.0786
Cont vs Expt	1	0.10530	0.10530	13.77	0.0008
Residual	33	0.25230			

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : V5

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.04624	0.04624	7.34	0.0106
Gender	1	0.00063	0.00063	0.10	0.0,7545
Age	1	0.00024	0.00024	0.04	0.8465
Race	2	0.02488	0.01244	1.98	0.1548
Cont vs Expt	1	0.16544	0.16544	26.27	0.0001
Residual	33	0.20781	0.00630		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length, gender, age and race)

	Variable				
Group	v1	v2	v3	v4	v5
Control	0.8163	0.6748	0.5621	0.5044	0.4188
Experimental	0.7253	0.5469	0.4463	0.3786	0.2611

APPENDIX TABLE 12 SUMMARY MANOVA APPROACH FOR PREMOLARS USING "NEW" LEVELS

(B) Reduced model (relative length, race and *Control and Experimental* groups)

MANOVA

Source	df	Wilk's Lambda	F - value	P - value
Relative length	1	0.737	2.2158	0.0778
Race	2	0.733	1/0423	0.4198
**Cont* vs *Expt*	1	0.477	6.79	0.0002

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *Control* and *Experimental* groups.

$D = 1.292v_1 - 0.0486v_2 - 0.3814v_3 - 1.137v_4 + 3.066v_5$

Univariate ANOVA tables

Variable : v1

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.000069	0.000069	0.02	0.8977
Race	2	0.003539	0.00177	0.43	0.6544
**Cont* vs *Expt*	1	0.05438	0.05438	13.19	0.0009
Residual	35	0.14428	0.00412		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v2

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.00193	0.0193	0.24	0.6244
Race	2	0.01627	0.00814	1.03	0.3681
**Cont* vs *Expt*	1	0.10572	0.10572	13.36	0.0008
Residual	35	0.27691	0.99791		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v3

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.01365	0.01365	1.85	0.1823
Race	2	0.04438	0.02219	3.01	0.0622
**Cont* vs *Expt*	1	0.09110	0.9110	12.36	0.0012
Residual	35	0.25805	0.00737		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v4

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.02311	0.02311	3.19	0.0825
Race	2	0.04324	0.002162	2.99	0.0633
*Cont vs Expt	1	0.10747	0.10747	14.86	0.0006
Residual	35	0.25319	0.00723		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v5

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.05049	0.05049	8.47	0.0062
Race	2	0.02420	0.01210	2.03	0.1464
*Cont vs Expt	1	0.16596	0.16596	27.85	0.0001
Residual	35	0.20854	0.00596		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups
(Adjusted for relative length and race)

	Variable				
Group	v1	v2	v3	v4	v5
Control	0.8169	0.6745	0.5616	0.5037	0.4194
Experimental	0.7270	0.5491	0.4452	0.3772	0.2623

APPENDIX TABLE 12 SUMMARY MANOVA APPROACH FOR PREMOLARS USING "NEW" LEVELS

(C) Minimal model (relative length and *Control and Experimental* groups)

MANOVA

Source	df	Wilk's Lambda	F - value	P - value
Relative length	1	0.063	2.0505	0.0970
*Cont vs Expt	1	0.451	8.0292	0.0001

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Discriminant function for *Control* and *Experimental* groups.

$D = 1.378v_1 - 0.0589v_2 - 0.4068v_3 - 0.3252v_4 + 2.235v_5$

Univariate ANOVA tables

Variable : v1

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.00018	0.00018	0.05	0.8327
*Cont vs Expt	1	0.07936	0.07936	19.86	0.0001
Residual	37	0.14782	0.00399		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v2

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.003327	0.003327	0.42	0.5210
*Cont vs Expt	1	0.16178	0.16178	20.42	0.0001
Residual	37	0.29318	0.007292		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v3

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.02174	0.02174	2.66	0.1114
*Cont vs Expt	1	0.16540	0.16540	20.24	0.0001
Residual	37	0.30243	0.00817		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v4

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.03316	0.03316	4.14	0.0491
*Cont vs Expt	1	0.18798	0.18798	23.46	0.0001
Residual	37	0.29642			

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : v5

Source	df	Type III SS	MS	F	P>F
Relative length	1	0.05470	0.05470	8.70	0.0055
*Cont vs Expt	1	0.21854	0.21854	34.74	0.0001
Residual	37	0.23274	0.00629		

*Cont vs Expt. = Control vs Experimental groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length only)

	Variable				
Group	v1	v2	v3	v4	v5
Control	0.8352	0.7135	0.6238	0.5655	0.4655
Experi-mental/	0.7441	0.5834	0.4923	0.4254	0.3144

APPENDIX TABLE 13 SUMMARY RESPONSE FEATURE APPROACH FOR PREMOLARS USING "NEW" LEVELS

(A) Full model (relative length, age, gender, race and *Control* vs *Experimental* groups)

Variable : vb0 (intercept from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	1.5306	1.5300	0.42	0.5197
Gender	1	0.0437	0.0437	0.01	0.9131
Age	1	1.151	1.151	0.32	0.5764
Race	2	1.346	0.673	0.19	0.8310
**Cont* vs *Expt*	1	13.915	13.915	3.85	0.0583
Residual	33	119.30	3.615		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb1 (slope from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.3316	0.3316	2.89	0.0987
Gender	1	0.0047	0.0047	0.04	0.8416
Age	1	0.0000	0.0000	0.00	0.9971
Race	2	0.5452	0.2726	2.37	0.1088
**Cont* vs *Expt*	1	1.6542	1.6542	14.41	0.0006
Residual	33	3.7894	0.1148		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb2 (curvature from fitted quadratic)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.00826	0.00826	0.65	0.4256
Gender	1	0.00020	0.00020	0.02	09001
Age	1	0.00328	0.00328	0.26	0.6148
Race	2	0.01007	0.00504	0.40	0.6757
**Cont* vs *Expt*	1	0.02774	0.02774	2.18	0.1489
Residual	33	0.4190	0.01270		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups

(Adjusted for relative length, gender, age and race)

Variable	*Control*	*Experimental*
ub0	0.9702	0.9245
vb1	-0.06119	-0.07695
vb2	0.000732	0.002773

APPENDIX TABLE 13 SUMMARY RESPONSE FEATURE APPROACH FOR PREMOLARS USING "NEW" LEVELS

(B) Reduced model (relative length, race and *Control* vs *Experimental* groups)

Variable : vb0 (Fitted quadratic : constant)

Source	df	Type II SS	MS	F	P>F
Relative length	1	0.00309	0.00309	0.90	0.3499
Race	2	0.001558	0.00078	0.23	0.7985
**Cont* vs *Expt*	1	0.01325	0.01325	3.85	0.0577
Residual	35	0.12045	0.00344		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb1 (Fitted quadratic : slope)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.3876	0.3876	3.85	0.0669
Race	2	0.5649	0.2824	2.61	0.0882
**Cont* vs *Expt*	1	1.6711	1.6711	15.42	0.0004
Residual	35	3.7942	0.1084		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb2 (fitted quadratic : curvature)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.01435	0.01435	1.19	0.2833
Race	2	0.01165	0.01165	0.48	0.6216
**Cont* vs *Expt*	1	0.02607	0.02607	2.16	0.1509
Residual	35	0.4308	0.01209		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups
(Adjusted for relative length and race)

Variable	*Control*	*Experimental*
vb0	0.9702	0.9258
vb1	-0.06125	-0.07701
vb2	0.000753	0.00272

APPENDIX TABLE 13 SUMMARY RESPONSE FEATURE APPROACH FOR PREMOLARS USING "NEW" LEVELS

(C) Minimal model (relative length and *Control* vs *Experimental* groups)

Variable : vb0 (fitted quadratic : intercept)

Source	df	Type II SS	MS	F	P>F
Relative length	1	0.00250	0.00250	0.76	0.3892
*Cont vs Expt	1	0.02316	0.02316	7.02	0.048
Residual	37	0.12201	0.00330		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb1 (fitted quadratic : slope)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.5178	0.5178	4.39	0.0429
**Cont* vs *Expt*	1	2.724	2.724	23.12	0.0001
Residual	37	4.359	0.1178		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Variable : vb2 (fitted quadratic : curvature)

Source	df	Type II SS ($x10^{-3}$)	MS ($x10^{-3}$)	F	P>F
Relative length	1	0.014144	0.01044	0.89	0.3521
**Cont* vs *Expt*	1	0.05769	0.05769	4.91	0.0329
Residual	37	0.43473	0.01175		

**Cont* vs *Expt.* = *Control* vs *Experimental* groups

Adjusted means for *Control* and *Experimental* groups
(Adjusted for relative length

Variable	*Control*	*Experimental*
vb0	0.9806	0.9314
vb1	-0.0540	-0.0709
vb2	-0.0000675	0.00239

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