AN INVESTIGATION INTO THE TREATMENT EFFECTS OF THREE ORTHODONTIC APPLIANCE PRESCRIPTIONS FOR THE CORRECTION OF CLASS II DIVISION 1 MALOCCLUSIONS

By

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DEDICATION

To my family and friends who have supported me through all my endeavors.

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STATEMENT OF THE PROBLEM

Until now, efforts to establish standards in health care have been based on establishing an ideal and working towards it. These ideals were set up by health care authorities and their basis was presumed to be "right".

Today, the model of perfection for health care is no longer created by one of "us", it has been created for us by the consumers and their representatives. These model makers are influenced by their own experiences, training, personal biases and political biases (Speidel, 1994).

The challenge we face now as orthodontists is to provide evidence-based quality care that meets the demands of our patients. No longer can we justify our choice in the type of provision of care on the basis of professional judgment. To address these issues, this investigation sets out to look at three treatment modalities commonly used in the correction of Class II division 1 malocclusions. Both a linear and an arch form analysis of tooth position in the transverse dimension were used to assess the changes brought about through the treatment provided, as well as assess the stability of these changes. Also, stability of tooth position in the transverse dimension will be assessed as an appropriate assay of the quality of orthodontic treatment provided.

ABSTRACT

Post-treatment changes in the orientation of the dentition occur in the majority of individuals subjected to orthodontic treatment. Most studies on the long-term stability of the arch following orthodontic treatment have reported variable and unpredictable results (Little et al., 1980). It is important to continue the search for specific factors which may be associated with post-treatment changes in the dentition so that orthodontists may plan the appropriate treatment and retention protocol.

The purpose of this study was to evaluate the treatment and post-treatment changes in a sample of patients with a Class II division 1 malocclusion (n = 50) who received orthodontic treatment and who were out of retention a minimum of 3 years. The entire sample was evaluated at three time periods (T1 = pre-treatment, T2 = post-treatment and T3 = post-retention). They were examined as a total sample and then broken down by treatment received, gender, arch and zone (molar, canine or incisor region). The following dental cast variables were measured to an accuracy of 0.01mm:

- intermolar width
- intercanine width
- incisor alignment

The means and standard deviations were then calculated for each parameter at each time period.

Repeat measures ANOVA analysis was performed to determine any clinically and statistically significant ($r > 0.6$, $p < 0.05$) association between variables. Multiple regression analysis was performed in an attempt to delineate any clinically useful pre- and post- treatment predictors of relapse in the transverse dimension.

For the purpose of this study, relapse is defined as any change in tooth position within the arch in the transverse dimension.

The form for both maxillary and mandibular dental arches for each patient at each time period was also investigated through a mathematical modeling programme which derived the eccentricity (e) of the arch form. Repeat measure ANOVA analysis was then used to define clinically or statistically significant ($r > 0.6$, $p < 0.05$) associations between this value and the other variables.

The results of both aspects of the investigation identified, the following trends:

- arch changes were independent of the type of orthodontic treatment
- arch form changed following the completion of all forms of active orthodontic treatment
- this "relapse" in orthodontic treatment appeared to be a function of the degree of orthodontic tooth movement

Although these findings relate to only one sub-category of Angle's Class II patients, they indicated that retainers were mandatory to maintain the changes subsequent to active orthodontic treatment. It was also apparent that the assessment of relapse, defined by changes in tooth position following orthodontic treatment, is an inappropriate assay of orthodontic quality assurance.

INTRODUCTION

Quality care encompasses both the choice in the care provided and the means in which that care is delivered and the long-term outcome of the treatment.

The major issues dealt with in this investigation will be discussed in the following sections:

- quality assurance
- origins of the quality of care debate
- measurement of the quality of care
- structure, process and outcome
- methods of quality assessment
- selecting data sources

1.1 Quality Assurance

Many issues confront today's orthodontists and other health care professionals. None is more controversial than the quality assurance debate. Just a few years ago, orthodontists could be confident that they alone had a social mandate to judge and manage the quality of care (Moyers, 1989). Now this mandate is frequently contested by patients, parents and other interested groups (Moyers, 1989). The very language of current discussions about quality assurance is often difficult to comprehend, and relates to such issues as outcomes and process measures, case-mix and case-security adjustments, profile, continuous quality improvement, total quality management, critical paths and appropriateness criteria.

Although many orthodontists have understandably reacted to this debate with anger, skepticism or disinterest, such reactions are luxuries that can no longer be afforded. Orthodontic specialists have legal and economic privileges granted by the public in the expectation that they have the technical orthodontic knowledge to be used in the best interest of the patient (Starr, 1982). If orthodontists cannot even understand, much less lead, the current debate about the quality of orthodontic care, their claim to technical mastery of their field will be openly challenged by other groups leading to the lack of specialist credibility. Even more troubling, if orthodontists lack a full comprehension of the quality of care debate, the public will lose confidence in their ability to serve and protect their patients in the face of changes now occurring in both privately and publicly funded health care programs. This is the cultural issue of this thesis.

Experts have struggled for decades to formulate a concise meaningful definition of care provided by health care professionals. The most recurring cited definition, formulated by the Institute of Medicine (Leape, 1994) holds that quality consists of the "degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge". Health care professionals naturally tend to define quality in terms of the attributes and results of care provided by practitioners (orthodontists) and received by the patients (Donabedian, 1980). Such definitions of quality emphasize the technical excellence with which care is provided and the characteristics of interactions between provider and patient (Lohr et al., 1992).

The technical quality of care is considered to have two principal components: the appropriateness of the service provided; and the skill to which appropriate care is performed. High technical quality consists of “doing the right thing” and this requires the right decision about care for each patient (high quality decisions making). To do it right requires the skill, judgment and the timeliness of execution (high quality performances) in diagnosis. This has been operationalized as the absence of relapse following orthodontic tooth movement.

The quality of the provision of care between orthodontist and patient therefore depends on several component relationships:

- the quality of their communication before, during and after therapy;
- the orthodontist's ability to maintain the patient's trust during and after therapy;
- the orthodontist's ability to treat the patient with "concern", empathy honesty, tact and sensitivity" (Mulley, 1995).

Although the perspectives of health care professionals are widely acknowledged to be important and useful, other perspectives on quality have been recently emphasized (Moyers, 1989). The most important change has been the growing recognition and insistence that care must be responsive to the preferences and values of orthodontic consumers, especially individual patients (Starr, 1982) and their opinions are important indicators of service quality. Hence the Institute of Medicine's definition of quality refers to health care that meets or exceeds the expectations of patients (Leape, 1994).

An interest in the views of patients is not fundamentally inconsistent with orthodontic views of quality, i.e., orthodontists have always acknowledged that satisfying patients (at some level) is essential to providing care of high technical quality, but this does not correlate with the patient's satisfaction. At the same time, however, orthodontists have often discounted the importance of patients' perception in the belief that patients have very limited knowledge of what constitutes technical quality and because of the difficulty of measuring patients' views accurately or reliably (Berg, 1991). This assumption is no long true, now that consumers are better educated dentally than in the past, whereas, the growing power of consumer advocating groups has also impacted this issue.

Another perspective on the quality of care, that has recently become more influential, is that of health care plans and organizations (Schroeder, 1996). Managed care organizations are involved with quality assurance for the services they fund. The emphasis on aspects of quality that are important to health care plans and organizations reflects not only the size and power of these organizations but also the recognition that orthodontic care has become a complex and technically sophisticated enterprise that is not inexpensive. Moreover, health care plans and organizations also tend to place great emphasis on the health of enrolled populations and on attributes of care that reflect the functioning of organizational systems (Blumenthal et al., 1996). From this perspective, definitions of the quality of care must take into account the extent to which care meets the needs and treatment wishes of a plan's enrollees as a group and allows for the possibility that when resources are scarce, quality may be improved by limiting the amount and/or specify the care some persons receive so that all members of the group receive equitable services.

Organized purchasers of health care services (unions) tend to be concerned about population-based measures of quality and organizational performance (e.g. the distinction between orthodontic care provided by generalists and specialists) (Moyers, 1989). This has culminated in the need to develop standards (i.e., measures of quality) that can be used by purchasers to compare the performance of health care plans and the providers on which they rely (Gold et al., 1995). The approaches used by such purchasers to measure and improve quality continue to evolve (Epstein, 1995), although the quality assurance assessments still tend to be largely subjective relative to other aspects of health care.

The current attention to the perspective of patient health care organizations in defining the quality of care may be dangerous if it encourages orthodontists to become cynical and disengaged. Moreover, the public remains vitally interested in the work of health care professionals (Gauzer, 1996) and expects them to be committed to improving the quality.

1.2 Origins of the Quality of Care Debate

Current concerns for the quality of dental (orthodontic) care are paradoxical. From a technical viewpoint, increases in the capabilities of orthodontic care are extraordinary. Decades of research have culminated in new techniques to improve the orthodontic status of patients (Proffit, 1986). Why, therefore, should the quality of orthodontic care be a concern? The first source of anxiety is that many orthodontists and their patients worry that quality will be jeopardized by efforts to reduce the burgeoning costs of health care, eg. reductions in insurance coverage for patients (Robinson et al., 1996); the organization of providers into competing managed care organizations (Basset et al., 1994); reductions in payments to providers (Gold et al., 1995); incentives to providers to assume financial risk for service costs (Gray, 1991), increases in the provisions of orthodontic care by general dentists and various forms of utilization review (Berwick, 1989). Even more troubling is the fact that many third party carriers (insurers) are plunging into arrangements that have previously been shown to have potentially adverse effects on the quality of care received by certain populations. For instance, the loss of third party insurance coverage results in fewer patients receiving appropriate orthodontic care, predisposing to future periodontal diseases (Vanarsdall, 1986) and also psychological disturbances (Proffit, 1986).

The need to reduce health care costs however, is compelling and orthodontists' failures in the past to participate in their control has undoubtedly contributed to this dilemma in an increasingly competitive market place.

Purchaser driven efforts to reduce orthodontic expenditures will undoubtedly be exacerbated in the future, and it would be both futile and counterproductive for specialists to reject these efforts outright. Nor must cost reduction always jeopardize quality, i.e., cost reduction and quality improvement are compatible goals when pursued appropriately (Wennberg and Gittelsohn, 1973).

Even if national expenditures on health care were not an overriding concern, the quality of care would still be an important topic. Pioneered by Wennberg and Gittelsohn (1973), clinical epidemiology has identified wide variations in the processes and outcomes of care among patients who receive routine orthodontic services for the same occlusal discrepancies by different providers. Politically, these variations have created the impression in the public's mind that much orthodontic practice lacks scientific foundation. This emboldens purchasers and third party policy makers to challenge orthodontists' claims that they know authoritatively what constitutes optimal care. The consequent erosion of the scientific credibility may then open the way for changes in financing that make orthodontists fearful for the quality of care they provide to their patients. By contrast, wide variations in the processes and outcomes of orthodontic care create opportunities for improvement. The critical challenge, then, is to identify the variations that produce the best outcomes (however they are to be measured). Thus a proper diagnosis leads to appropriate treatment (Graber, 1986).

1.3 Measurement of the Quality of Care

Professional judgment has been the primary criterion that ensured patients received high quality care. This situation is now changing. Practice patterns and the quality of health care vary much more than had been previously realized. The ability to measure the quality of care has also advanced considerably and clinicians are increasingly interested in having objective information about their practices. Both patients, insurers and purchasers may also be expected to know more about the determinants of quality of care.

Rudimentary methods to monitor care (e.g. utilization review, profiling) are now widely used by third parties to improve the efficiency of care. Because these approaches are often described as measuring quality, they are generally assumed to be the best available, even though they are based largely on administrative or billing data and lack clinical details. This assumption is wrong. Sophisticated and efficient methods of measuring quality are available to help clinicians and institutions to improve service quality; albeit with two important caveats:

a) it will never be possible to produce error-free assessments of the quality of care, although every effort should be made to use state of the art measures, even if additional expenditure are required.

b) the quality of care can be assayed from several vantage points from cases provided by individual professionals.

1.4 Structure, Process, and Outcomes

Quality of care can be evaluated on the basis of three parameters, namely structure, process and outcome (Donabedian, 1980, 1982, 1985; Brook et al., 1977, 1979; Lohr et al., 1986). Structural data are the characteristics of professionals and institutions/practices, whereas process data are the components of the encounter between orthodontists/auxiliaries and their patients. Outcome data refer to the patients' subsequent orthodontic status following treatment (i.e., before or after treatment). If quality-of-care criteria based on structural or process data are to be credible, it must be shown that variations in the attribute measured lead to differences in outcome. If outcome criteria are to be credible, it must also be demonstrated that differences in outcome will result with variation in the processes of care under the control of health professionals.

Critics of the use of process data to measure the quality of care worry that they are unimportant outcome predictors. They therefore argue that if resources were directed to improvements in the process of care represented by these measures, then the cost of orthodontic care might increase without producing corresponding oral health improvements (Donabedian, 1982).

Critics of the use of outcome measures believe that most differences in outcomes among patients receiving the same treatment are the result of factors not under the control of the orthodontist (e.g. differences in patients' morphological and functional characteristics). They therefore argue that assessments of treatment based on outcome measures may be invalid.

When used appropriately, however, both process and outcome measures can provide valid assays of the quality of care. Process data are usually more sensitive measures of quality than outcome data, because a poor outcome does not occur every time there is an error in the provision of care (Graber, 1986).

1.5 Methods of Quality Assessment

There are five basic methods for the assessment of service quality on process data, outcome data or both (Brook et al., 1973). The first three methods are implicit, i.e., there are no prior standards or agreements about what reflects good or poor quality care. With each of these methods, case records (after care has been provided) are reviewed to answers one of the following questions:

1. was the process of care adequate?
2. could different treatment have improved the outcome?
3. was the overall quality of care acceptable?

The fourth method evaluates the provision of care against explicit process criteria (Ashton et al., 1994), where the result is expressed as the proportion of satisfied criteria. The fifth method uses explicit *a priori* criteria to determine whether the observed results of care are consistent with the outcome predicted by a model validated on the basis of scientific evidence and clinical judgment. The results of these assessments will then vary according to the method used. The explicit process method is most stringent and the implicit outcome method the least. The assessment of quality should therefore depend more on process than outcome data, especially when these systems are used to compare individual orthodontists.

1.6 Selecting Data Sources

After deciding which method of quality assessment is to be used, the next step is to determine the appropriate data sources (e.g. see Chapter 3). Data used in quality assessment are obtained from diverse sources e.g. records maintained by insurance companies, clinical records by orthodontists, epidemiological survey data and direct observations of the orthodontist/patient encounter. Each data source produces a different aspect of the quality of care (Wilson and McDonald, 1994). The selection then depends on the purpose of the assessment, for instance, the Aging for Health Care Policy and Research has used both literature reviews and expert opinion to establish guidelines for care and quality of care criteria (Basset et al., 1994; Wenger et al., 1995). Unfortunately, analogous parameters have yet to be established for orthodontic care assessment. The scientific literature has been used to develop evidence-based practice guidelines in medicine (Eccles et al., 1996, North of England Asthma Guideline Development Group 1996; North of England Stable Angina Guideline Development Group, 1996), and to evaluate the appropriateness of use (Bernstein et al., 1992; McGlynn et al., 1992) of procedures, but again orthodontic assessments remain subjective.

To be useful, criteria must be as clinically detailed as possible to yield assessments of orthodontic quality. The development of such criteria is critical to the future of orthodontics, i.e., to ensure that all patients receive the highest quality of care on the basis of scientific data and expert judgment.

With all these issues in mind, the purpose of this study was to evaluate the quality of orthodontic care, by the analysis of treatment effects of three orthodontic prescriptions used to correct Class II division 1 malocclusions. This was done via a linear analysis that recorded changes in tooth position in the transverse dimension (occlusal). In addition, an analysis of arch form was expressed mathematically to delineate the changes induced by the various treatments. These changes caused by treatment were then compared with changes seen in an untreated population with the same malocclusion.

LITERATURE REVIEW

The purpose of this investigation was to examine the effect of three treatment modalities used for the correction of Class II division 1 malocclusions, to compare them with those observed in an untreated population with the same malocclusion, to assess the stability of treatment -induced changes and to evaluate whether the measurement of tooth position stability in the transverse dimension is an appropriated assay of treatment quality.

To address the issues surrounding the parameters of this investigation, the literature review is discussed under the following headings:

- the assessment of orthodontic quality service
- reasons for choosing Class II division 1 malocclusion
- treatment modalities used in the correction of Class II division 1 malocclusions
- factors influencing arch form
- dental arch descriptors

2.1 The Assessment Of Orthodontic Service Quality

Whether dependent on public or private funding, there is an obligation to ensure that patients' perceptions of orthodontic service quality match or exceed their expectations. This may be difficult to achieve since orthodontically induced changes in dental arch width and length may return to pre-treatment values after retention (Steadman, 1961; Shapiro, 1974; Johnson, 1977; Little et al., 1981). This matter is not minor, since dental arch changes may variably involve both size and shape parameters. Yet, their definition has been unacceptably imprecise and subjective (Sampson, 1981). There is also a general consensus that minimal alterations to the original arch form during treatment may reduce the prevalence of post-retention changes (Joondeph et al., 1970). Unfortunately, there are no scientific data to support such a consensus. There are also patients whose arch forms require significant changes during treatment. For example, in patients with Class II division 1 malocclusions, marked changes in maxillary arch form may be crucial to accommodate the functional occlusal relationships with the mandibular arch. If post-retention relapse occurs in these patients, then the resultant reduction in their perceptions of service quality may detract from their satisfaction.

This is not an insignificant problem. There is a report that 70% of dental arches revert to their original shape during the post-retention period (Felton et al., 1988), although the technique used in this study to define these post-retention changes remains ill defined. Another study has noted analogous changes in mandibular dental arch form 10 years post-retention (Joondeph et al., 1970), although again the techniques used to quantify the relapse remain obscure. In a more definitive study (De La Cruz et al., 1995), a general pattern of post-retention relapse of the treatment changes in arch form was noted in patients with both Class I and II malocclusions, although their accurate prediction was precluded by the degree of individual variability. Nevertheless, these data suggest that post-retention changes in arch form are only moderately associated with those induced by orthodontic treatment. Thus there is a general consensus that small treatment changes result in minimal post-retention relapse, while large post-retention changes may characterize cases with large treatment changes. These findings are consistent with the claims of other investigators (Joondeph et al., 1970; Strang, 1949).

The impact of many variables affecting dental arch form requires further investigation. For instance, whereas changes in dental arch form from orthodontic treatment are generally much greater for the maxillary arch in Class

II than Class I malocclusions, they appear to undergo analogous post-retention changes (De La Cruz et al., 1995). There is also evidence that reductions in dental arch width and length and increased crowding occur in all patients during the post-retention period, irrespective of whether the original intercanine width was maintained, reduced or increased during treatment (Little et al., 1981). This conflicts with traditional dogma, that patients requiring tooth extraction are more likely to exhibit significant changes in dental arch form due to orthodontic treatment than those where the treatment objectives can be accomplished without extraction (Angle, 1907). Moreover, changes in dental arch width and length do not appear to be associated with changes in arch form within or between different sequences of orthodontic treatment, although this finding may be partly due to the lack of precise techniques for their assessment (Walter, 1953; Shapiro, 1974).

These findings have important consequences for the quality assurance of orthodontic treatment. For instance, if there is a post-retention tendency for dental arch form to revert back to pre-treatment form, then stability might be anticipated to be maintained after retention if the original arch form is maintained during treatment. Unfortunately, long-term stability is not necessarily ensured by minimally altering the patient's original pre-treatment arch form (Riedel, 1960). The high degree of variability observed in the post-retention response to treatment changes also hampers future predictions (Riedel, 1960). This is illustrated by the lack of differences in post-retention changes following the orthodontic treatment of maxillary arches with tapered shapes, flared incisors and constricted intercanine widths relative to those with Class I malocclusions (De La Cruz et al., 1995). In fact, marked relapse may occur in both Class I and Class II division 1 cases. Class II cases may not exhibit more relapse than Class I individuals, even though their arch forms may be changed more during treatment (De La Cruz et al., 1995), since the correlation between the changes due to treatment, compared with those that occur during post-retention, is low for Class II cases. Conceivably, these latter cases exhibit a greater variety of responses than those that characterize Class I malocclusions. Thus although arch form may be changed by a variety of orthodontic or even orthognathic techniques, the long-term instability may be unacceptable without the provision of permanent retention devices (Graber and Vanarsdall, 1994). This then poses a variety of other questions:

- if some patients are more prone to relapse than others, what information is required for their precise identification?
- if relapse is preferentially predisposed in some regions (e.g. the anterior segment) relative to others (e.g. the posterior segment), how might these changes be minimized?
- are retainers required to be worn for life after orthodontic treatment?
- are retainer designs effective in the prevention of relapse?
- if retainers predispose to other dental diseases (e.g. plaque retention) that may subsequently jeopardize the esthetic objective, are they unnecessary for some patients?

These questions are equally significant. The main objective of this study is to examine the phenomenon of post-orthodontic treatment relapse with a greater degree of precision than previous reports in the literature. The primary intent is to reduce as far as possible the degree of subjectivity in dental arch assessments. For instance, the technique of using photocopies of dental study casts (De La Cruz et al., 1995) may be criticized due to the potential for image distortion. Similarly, traditional methods for the assessment of dental arch size and shape involving the use of caliper measurements are unacceptably crude relative to the potential precision of modern digital imaging techniques (Sampson, 1981). Other significant criticisms of previous studies on post-orthodontic treatment relapse center on their sampling limitations, i.e., routine edgewise orthodontic treatment in the study of De La Cruz et al., (1995) as opposed to this study that includes the assessment of three treatment modalities.

In view of the importance of this topic, the current study was undertaken to obtain more accurate assessments of post-orthodontic treatment relapse. The primary intent was to develop guidelines for their subsequent prevention (i.e., is analysis of tooth movement in the transverse dimension an appropriate assay of quality of treatment). This topic is particularly pertinent at this time, as the potential for post-orthodontic treatment relapse may well serve as an important quality assurance assay for Third Party providers in this era of increasing fiscal restraint.

2.2 Reasons For Choosing A Class II Division 1 Sample Group

Class II division 1 was selected as the sample group for this investigation on the following criteria:

- 40-44% incidence in the North American population (Proffit, 1986);
- variation in treatment modalities including both extraction and nonextraction methods (Proffit, 1986);
- discrepancies in shape when comparing the maxillary and the mandibular arches (Lavelle, 1975);
- the prevalence of post-treatment relapse as defined from previous studies (Little et al., 1981; Franklin, 1996).

2.3 Treatment Modalities Used In The Correction of a Class II Division 1 Malocclusion

Due to the independent development of the specialty of orthodontics, different techniques have been developed and utilized in the correction of a Class II division 1 malocclusion. Some of these modalities include the use of functional appliances, headgear, removable appliance, fixed appliances, extraction of teeth, orthognathic surgery and a combination of the aforementioned (Proffit, 1986). The treatment modalities assessed in this study are those used by the Burlington Study Group (Popovich, 1991) plus a 'recent' straightwire technique used at the University of Manitoba Graduate Orthodontic Clinic.

2.4 Factors Influencing Arch Form

The development of arch form depends on both intrinsic and extrinsic factors. Some of these factors may serve as criteria for exclusion (habits, injury, caries), while others cannot be assessed or predicted but may influence arch form. Some of these influencing factors are summarized in Table 2.4.1.

Table 2.4.1 Factors Influencing Arch Form

INTRINSIC	EXTRINSIC
• heredity of jaw size (Proffit, 1986) • heredity of tooth size (Proffit, 1986) • muscle distribution and function (Scott, 1938) • eruption pattern of teeth (Dale, in Graber 1994) • pathology (Graber, 1994)	• habits (digit sucking, pen chewing) (Proffit, 1986) • injury (Graber, 1994) • caries (Graber, 1994) • early loss of dentition (Graber, 1994)

2.5 Dental Arch Form Descriptors

As the description of arch form and tooth location is crucial to the assessment of relapse, a review of the methods used by previous workers is included in this review. Tables 2.5.1-2.5.5 illustrate the most pertinent investigations of the stability of teeth within the arch.

Early investigators studied arch form with the hope of improving prosthetic appliance designs (Bonwill, 1884 - 1885). Only recently has arch form been recognized as an important parameter in planning orthodontic treatment. One of the earliest description of the normal anatomical arrangement of the teeth in the dental arch was provided by Hunter (1839). In his dental anatomy textbook, Black contended that the maxillary teeth are arranged in a semi-ellipse, with the long axis passing though the central incisors (Black, 1902). The mandibular teeth were then considered to be arranged on a similar but smaller curve, with the line of the ellipse falling on the buccal cusps of the molars as opposed to the premolars for the maxillary arch. By contrast, Broomwell noted that the teeth of both arches are arranged in the form of two different parabolic curves (Broomwell, 1902) and this concept was accepted in the seventh edition of Angle's book, albeit with recognition of its inherent individual variability (Angle, 1907). A symmetroscope was later devised by Gruneberg (1912), and modified by Friel (1914), to measure dental arch symmetry. Williams (1917) subsequently described the position of the six maxillary anterior teeth defined by the arc of a circle with its center midway between the buccal grooves of the first molars, whereas Hellman (1919) concluded that the mathematical methods to define arch form were unacceptable. Subsequent investigations based on standard engineering principles of the time, showed that dental arch form could be defined by various curves, including ellipses, parabolas, cubic parabolas and 'horse-shoes' with parallel sides Stanton, 1922), whereas earlier dental arch assessments were based on a series of templates (Gilpatric, 1923). The fact that the variability of dental arch form cannot be defined by such graphic methods led to their condemnation by Izard (1927) who held that 75% of normal dental arches were defined by an ellipse to provide the most appropriate definition of dental arch form, whereas MacConaill and Scher (1949) considered that catenary curves were more appropriate descriptors. Subsequently, Sved (1952) suggested that the dental arches could be defined by sections of spheres with differing radii, which were then used to plan the potential orthodontic treatment. By contrast, Lu (1964) defined a series of polynomials to describe dental arch form, whereas Kato and associates devised a series of polygonal descriptors to summarize arch forms based on the average coordinates of specific datum points (Kato et al., 1964). The definition of dental arch form has proved a significant challenge and several investigators contended that their geometric comparison is precluded by the inherent inconsistency (Hellman, 1919; Wheeler, 1950). Thus although 'normal' dental arch forms may approximate certain geometric curves (Izard, 1927; Lasher, 1934; MacConaill and Scher, 1949), there is no consensus regarding the most appropriate descriptor.

Traditionally, most studies of dental arch form have centered on the examination of growth changes (Table 2.5.1), although there have also been many investigations on the impact of extraction versus non-extraction on the orthodontic movement of teeth within the arch (Table 2.5.2). In addition, a variety of techniques have been used to describe dental arch form (Table 2.5.3), although they have yielded only limited information on the potential for dental arch relapse in the post-retention period (Table 2.5.4). Although more sophisticated techniques have been applied to the analysis of early changes in arch form (Table 2.5.5), the application of these and other data for the prefabrication of arch wires remains problematical (Table 2.5.5).

TABLE 2.5.1 DENTAL CHANGES IN UNTREATED NORMAL OCCLUSIONS

AUTHOR	METHOD	SAMPLE SIZE	RESULTS
Sillman (1935)	• longitudinal study from birth to age 25 years	65, normal whites	1. From birth to age 2 there is an increase of 5 mm in intercanine width. The width continues to increase until 12 years in the mandible and 13 years in the maxilla at which time it ceases. 2. In the deciduous stage there is an increase of 0.5 mm/year in the maxilla and 0.2 mm/year in the mandible. this dimension shows no change after age 14 years.
Cohen (1940)	• longitudinal study	28, multiracial, from ages 2-14 years	1. The greatest lateral growth of the dental arches occurs in the canine region of both arches. 2. Intercanine width is greatest at age 8.5 years and then shows little change.
Barrow and White (1952)	• retrospective study from dental casts	51, from birth to age 18 years	1. 5% showed a tapered arch form, 65% showed a trapezoidal arch form, 30% showed an ovoid arch form. 2. Little intercanine width change from age 3-5 years,;it increased rapidly from ages 5-8/9 years (4 mm in the maxilla and 3 mm in the mandible); the intercanine width steadily increased (between 0.5 mm-1.5 mm) until the age of 14 years. 3. The average intermolar width increased from age 7-11 years (max avg=1.8 mm, mand avg=1.2 mm). The intermolar width decreased between the ages of 11-15 years (max avg=0.4 mm, mand avg=0.9 mm). 50% of the cases showed a continued trend to decrease intermolar widths between the ages of 15-17 years.
Lundstrom (1969)	• prospective study	100 pairs of twins from ages 9-32 years	1. A reduction of spacing of the dentition and an increase of crowding is a normal development of the dentition. 2. There is a greater decrease in the anteroposterior dimension compared with the transverse.
Sinclair and Little (1983)	• retrospective study from dental casts	65 untreated normal occlusions	1. Both genders showed a decrease in intercanine width from the mixed dentition stage to the permanent dentition stage which continued into the early adult stage (19-20 years). 2. Males showed small insignificant increases in the intermolar width up to the early adult stage whereas females showed a statistically significant loss in intermolar width with the majority happening in the early adult stage. 3. Both genders showed an increase in incisor irregularity into the early adult stage.

Table 2.5.2 EXTRACTION / NONEXTRACTION TREATMENT AND STABILITY OF THE DENTITION

AUTHOR	METHOD	SAMPLE SIZE	RESULTS
Walter (1953)	• retrospective study from dental casts	• 102 white males and females, ages 6-36 years	1. 85% showed expansion of arch width as a result of treatment (range=0.1-12.8 mm). 2. 15% showed a decrease of arch width as a result of treatment (range=0.1-11 mm). 3. Intercanine width increased from 0.1-8.4 mm. 4. Intermolar width increased from 0.3-8.3 mm. 5. 12% of those expanded showed a relapse in width. 6. 95% of maxillas expanded retained their increased widths whereas only 79% of mandibles expanded retained their widths.
Shapiro (1974)	• retrospective study looking at dental casts taken at pretreatment, end of treatment, and 10 years out of retention • class I and II malocclusions • extraction and non-extraction therapy	• 80 cases	1. Mandibular intercanine width demonstrated a strong tendency to return to its pretreatment dimension in all groups but especially in the Class II div. 2 cases. 2 There was a greater decrease in mandibular intermolar width from pretreatment to post treatment in the extraction group when compared to the nonextraction group.
Gardner and Chaconas (1976)	• retrospective study from dental records • class I and II malocclusions	• 103 cases, 74 non-extraction, 29 extraction • 62 females and 41 males	1. Intercanine width that was expanded through treatment showed a strong tendency to relapse post treatment in both nonextraction and extraction cases. 2. The intermolar width of nonextraction cases showed a significant increase with treatment. The extraction cases showed a significant decrease with treatment. There were no changes in either extraction or nonextraction cases postretention.
Hechter (1978)	• retrospective study • compared normal, Class I, Class II div. 1, Class II div. 2 and Class III	• 94 patients	1. Three symmetry indices were devised to describe dental arch asymmetries quantitatively. 2. Dental arch asymmetry is independent from and randomly distributed throughout Angle's malocclusion classification 3. The dental arches of the untreated "acceptable" normal occlusion patients were not perfectly symmetrical and differed statistically from the pre-orthodontic treatment case values which were more severely affected. 4. Pretreatment asymmetries tend to return postretention.
Little, Wallen and Riedel (1981)	• retrospective study from dental records • class I and II malocclusions	• 65 cases • extraction of first premolars • edgewise mechanics	1. Long term alignment was variable and unpredictable. 2. No descriptive characteristic was of any predictive value. 3. Arch width typically decreased after retention whereas crowding increased. This occurred in spite of treatment maintenance of initial intercanine width, treatment expansion or constriction. 4. Success at maintaining satisfactory mandibular anterior alignment was less than 30%, with nearly 20% of the cases showing marked crowding many years after removal of retainers.
Sadowsky and Sakols (1982)	• retrospective study from dental records • class I and II malocclusions	• 96 cases • extraction and non-extraction cases • edgewise mechanics	1. 72% exhibited less than the ideal dental relationship achieved through treatment after cessation of retainer wear. 2. 9% showed increased mandibular incisor crowding.
Glenn, Sinclair and Alexander (1987)	• retrospective study from dental records • class I and II malocclusions	• 28 cases • nonextraction cases	1. Intercanine width decreased significantly at post retention despite minimal changes through treatment. 2. Intermolar width remained relatively stable post retention. 3. Incisor irregularity increased at post retention but a long term improvement was still evident.
Little, Riedel and Artun (1988)	• retrospective study from dental records	• 31 cases • first premolar extraction cases • evaluated pre-treatment, end of treatment, 10 years post retention and 20 years post retention	1. Crowding continued to increase during the 10- to 20- year post retention phase but to a lesser degree than from the end of retention to 10-year post retention phase. 2. Only 10% were judged to have acceptable incisor alignment at the 20-year post retention phase.

Little, Riedel and Stein (1990)	• retrospective study from dental records	• 26 cases • mixed dentition patients with inadequate pretreatment mandibular arch length • nonextraction therapy	1. Intercanine width decreased after treatment whether the case was expanded or not through treatment. 2. Mandibular anterior crowding during the post treatment phase is a phenomenon that continues well into the 20 to 40 age bracket and probably beyond. 3. Most of the trend towards constriction of arch width occurs before age 30 and it often continues well past the cessation of facial growth.
Little, Riedel and Engst (1990)	• retrospective study from dental records	• 30 cases • mixed dentition cases with serial extraction of deciduous teeth and extraction of first premolars- • edgewise mechanics	1. 73% of cases showed clinically unsatisfactory mandibular incisor alignment 10 years post retention. 2. Intercanine width decreased in all but one of the cases 10 years post retention. 3. There was no difference between the serial extraction group and a matched sample extracted and treated after full eruption.
McReynolds and Little (1991)	• retrospective study from dental records	• 46 cases • extraction of mandibular second premolars in mixed dentition and in permanent dentition • edgewise mechanics	1. No difference in stability between the two groups. 2. Arch width decreased with time. 3. Incisor irregularity increased throughout the post retention phase.
Paquette, Beattie and Johnston (1992)	• retrospective study from dental records	• 63 cases • class II div. 1 malocclusion • nonextraction and extraction therapy • edgewise mechanics	1. Both groups showed less than 3.5 mm of lower anterior irregularity post retention. 2. The pattern of relapse was unrelated to the treatment provided.
Rossouw, Preston, Lombard and Truter (1993)	• retrospective study from dental records	• 88 cases • class I, II and III malocclusions • extraction and nonextraction therapy	1. Ideal treatment goals are essential if acceptable stability of orthodontic treatment is to be achieved. 2. Expansion of the mandibular arch beyond the original intercanine width is likely to lead to failure as this dimension tends to decrease beyond the original measurement in the long-term. 3. The orthodontist cannot be held responsible for natural changes that might have influenced an ideal treatment result.
Bishara, Bayati, Zaher and Jakobsen (1994)	• retrospective study from dental records	• 46 cases • class II div 1 malocclusion • extraction and nonextraction therapy	1. Both males and females in the extraction group had a net decrease in the maxillary intermolar width, whereas those in the nonextraction group experienced an increase in this dimension. 2. Both grouped showed a decrease in mandibular intercanine width post retention.
Sadowsky, Schneider, BeGole, and Tahir (1994)	• retrospective study from dental records	• 22 cases • nonextraction therapy • edgewise mechanics	1. Both maxillary and mandibular intermolar width decreased in the post retention phase. 2. Only mandibular intercanine width changed (decreased) in the post treatment phase. 3. Mandibular anterior segment demonstrated relatively good alignment throughout the post retention phase.

Table 2.5.3 DESCRIPTION OF ARCH FORM

AUTHOR	METHOD	SAMPLE	RESULTS
Currier (1969)	• retrospective study	• 25 radiographs of the occlusal view of a pair of plaster dental casts	1. The ellipse provides a good mathematical description of the outer curve (facial periphery) of the maxillary and mandibular dental arches. 2. The parabola provides a good mathematical description of the inner curve of the maxillary and mandibular dental arches.
Hechter (1978)	• retrospective study • compared normal, Class I, Class II div. 1, Class II div. 2 and Class III	• 40 patients	1. The analysis of arch form based on mathematical geometric configurations suggest that the parabola had a very high "goodness of fit" to both the maxillary and mandibular arches.
Sampson (1981)	• statistical analysis of dental casts	• 66 cases • maxillary casts only	1. Arcs of conic section can be used to model the shapes of dental arches.
Felton, Sinclair, Jones and Alexander (1988)	• a computer assisted analysis of dental casts	• 30 casts of untreated mandibular arches • 30 casts of Class I nonextraction patients • 30 casts of Class II nonextraction patients	1. Cases that had changes in arch form during nonextraction treatment were frequently unstable. 2. Customizing arch forms appears to be necessary in many cases to obtain optimum long term stability because of the great individual variability in arch forms found.
Jones and Richmond (1989)	• a computer assisted analysis of dental casts	• 28 pairs of dental casts of orthodontically treated patients	1. The parabola fits the middle curve of the lower dental arch. 2. The parabola fits the post treatment cast better than the pre treatment casts. 3. The parabola fits as well as any ideal asymmetrical curve and is adequate in crowding analysis. 4. Tthe incorporation of a more flexible curve form allowing for arch asymmetries into tooth crowding analysis systems should theoretically improve the fit in upper pre-treatment dental arches and thus reduce bias in serial assessment of tooth crowding.
Ferrario, Sforza, Miani and Tartaglia (1994)	• a computer assisted analysis of dental casts	• 50 untreated males, 45 untreated female • normal dentition • age range 20-27 years	1. Maxillary and mandibular arches can be adequately expressed mathematically by a fourth order polynomial. 2. The maxillary arch was wider than the mandibular arch independent of gender. 3. Gender differences were found but in the order of size and not form. 4. The polynomial expression allowed evaluation of asymmetry.
Battagel (1996)	• a computer aided analysis of dental casts	• 35 cases • included normal occlusions, Class I, II and III malocclusions	1. Catenary curves do not approximate arch form well. 2. Catenary curves are not suitable for use in the calculation of valid crowding indices. 3. The discrepancy between arch perimeter calculated by the catenary method and any other mathematical method can be up to 5% in well aligned arches.

Table 2.5.4 EFFECT OF ORTHODONTIC TREATMENT ON ARCH FORM

AUTHOR	METHOD	SAMPLE	RESULTS
Hellman (1940)	• retrospective study from dental records	• 16 cases • Class I malocclusion	1. By achieving an ideal finish you would ensure stability of treatment results.
Walter (1953)	• retrospective study from photographs of dental casts	• 102 cases • age 6 to 36 years • treated by a variety of orthodontists • nonextraction therapy	1. Arch form can be permanently altered and the changes maintained.
Johnson (1977)	• a review of 11 American Board cases	• 11 patients with a variety of treatment	1. Intercanine width was most likely to decreased after treatment. 2. Intermolar width is apt to decrease from the beginning of treatment through the post retention phase. 3. Lower arch crowding may be due to multiple factors: expanded canines; protrusive and proclined incisors; and late skeletal growth.
De La Cruz, Sampson, Little, Artun, and Shapiro (1995)	• a retrospective study from dental casts	• 45 patients with Class I malocclusion • 42 patients with Class II malocclusion requiring extraction of four first premolars	1. A rounding of arch form during treatment followed by a change to a more tapered form in the post retention phase. 2. The greater the treatment change, the greater tendency towards post retention change. 3. The patient's pretreatment arch form was the best guide to future arch form stability, but minimizing treatment changes was no guarantee of post retention stability.

Table 2.5.5 DEVELOPMENT OF ARCH FORM IN NORMAL UNTREATED POPULATION

AUTHOR	METHOD	SAMPLE	RESULTS
Cohen (1940)	• longitudinal study over 11 years	• 28 cases, ages 2-14 years • multiracial sample	1. The greatest lateral growth in he dental arch occurs in the canine area. 2. The mandibular intercanine width reaches its maximum by age 8.5 years and from then there is little growth. Growth at the maxillary intercanine region is greatest between ages 5 to 8 years and continues until age 12 years with little growth after that.
Scott (1957)	• looked at the development of human jaws embryologically	• none mentioned	1. The primordial jaw cartilages developed in a series of similar catenary-like arches. 2. In post-natal life the dental arches may deviate from this form but the basal bone of the jaws remains more constant. 3. The deviation in dental arch form is due to the nature of alveolar growth and not to the pressure effect of adjacent tissues.
Pepe (1975)	• a computer aided curve fitting investigation	• 7 cases	1. A sixth degree polynomial is a good mathematical expression of arch form. 2. The catenary curve was found to be the least descriptive.
Hechter (1978)	• retrospective study • compared normal, Class I, Class II div. 1, Class II div. 2 and Class III	• 94 patients	1. Three symmetry indices were devised to describe dental arch asymmetries quantitatively. 2. Dental arch asymmetry is independent from and randomly distributed throughout Angle's malocclusion classification 3. The dental arches of the untreated "acceptable" normal occlusion patients were not perfectly symmetrical and differed statistically from the pre-orthodontic treatment case values which were more severely affected. 4. Pretreatment asymmetries tend to return postretention. 5. The analysis of arch form based on mathematical geometric configurations suggest that the parabola had a very high "goodness of fit" to both the maxillary and mandibular arches.
Raberin et al. (1993)	• a computer aided investigation	• 278 cases, mandibular arches • ages 17-30 years	1. The idea of a single ideal arch form could not be substantiated in this group of untreated adults. 2. Five arch forms plus a guide to their determination was fabricated for clinical use.

The majority of studies on dental arch form have focused on single shapes to describe the dental arches of particular patient samples. Early evaluations were, however, largely subjective, too reliant on personal opinion and clinical observation, and could not withstand critical scientific scrutiny (Hrdlicka, 1916; Williams, 1917; McCoy, 1919; Hellman, 1940). Hechter (1978) looked at a sample of 94 patients to evaluate the changes in arch form seen in a normal population, and in those with Class I, Class II division 1, Class II division 2 and Class III malocclusions. Three symmetry indices were devised to describe dental arch asymmetry quantitatively. This study showed that dental arch asymmetry was independent of, and randomly distributed among, Angle's classifications and that the dental arches of the untreated normal occlusion sample were not perfectly symmetrical. More recent assessments have used various mathematical descriptors, including orthogonal polynomials (Lu, 1967) cubic splines (BeGole, 1980), parabolas (Mills et al, 1965) ellipses (Currier, 1969; Biggerstaff, 1972; Sampson, 1981; Brader, 1972), catenary curves (MacConaill and Scher, 1949; Pepe, 1975) and their derivative conic sections (De La Cruz et al., 1995). All these previous studies exhibited various shortcomings. This begs the question of their relevance to current post-retention assessments. Other criticisms that augment such controversies, include the following:

- limited sample sizes (e.g. Hellman, 1940(16); Cohen, 1940(28); Currier, 1969(25); Pepe, 1975(7); Johnson, 1977(11); Glenn et al., 1987(28); Little et al., 1988(31); Jones et al., 1989(28); and Sadowsky et al., 1994(22);
- consolidation of data from the correction of different malocclusion (e.g. Walter, 1953; Shapiro, 1974; Gardner et al., 1976) or treatment modalities (e.g. Walter, 1953; Shapiro, 1974; Sadowsky, 1982; Felton, 1987; Little et al., 1990; Rossouw, 1993; Bishara, 1994);

- assumption that growth changes of individuals are analogous to those of a population (e.g. Sillman, 1935; Cohen, 1940; Barrow and White, 1952; Lundstrom, 1969; Sinclair et al., 1983; Ferrario et al., 1994; Battagel, 1996);
- the search for the ideal arch form as a standard of care, rather than the treatment of patients as individuals (e.g. Cohen, 1940; Scott, 1957; Pepe, 1975; Raberin, 1993).

2.6 OBJECTIVE OF THE STUDY

In order to address the two main issues of sample limitation and variable precision of assessment techniques, the primary aims of this study may be summarized as follows:

1. to examine the effect on tooth position and arch form of three treatment modalities used to treat Class II division 1 malocclusion;

2. to assess the stability of arch form induced by these treatments;

3. to assess the changes due to relapse relative to those in an untreated group with the same malocclusion;

4. to develop a method that reduces the degree of subjectivity in dental arch assessment;

5. to evaluate whether the assessment of tooth stability provided a valid assay of orthodontic treatment quality.

MATERIALS & METHODS

3.1 Introduction

The purpose of this study was to investigate the effects of three treatment modalities to correct Class II division 1 malocclusions. According to the classification used by the Burlington Study Group, the three treatment modalities investigated were:

- **limited treatment** - which consisted of the use of bite planes, monoblocs, headgear therapy or a combination of the three;
- **compound treatment** - which consisted of full arch banding with a standard edgewise setup plus a currently used straightwire technique;
- **recent treatment** - which consisted of full arch banding with a modified Roth prescription.

The effects of the treatments were compared amongst themselves as well as with a **control group** which received **no treatment** matched for gender, race, and degree of malocclusion.

In this study, post-treatment relapse was used to define the effectiveness of treatment for the correction of Class II div. 1 malocclusions since:

- relapse can be objectively evaluated from study models;
- alternative parameters e.g. facial profile (Legan, 1992), cephalometric values (Arnett, 1993), and speech (Chate, 1994) have either an inadequate scientific basis (Moyers, 1989) or cannot be assessed quantitatively (Berg, 1991).

Initially a pilot study was undertaken to define the incidence, amount and area of relapse and to refine the techniques to assay tooth position changes within the arch. The objective was then to apply these results to a definitive study of 50 patients.

3.2 Pilot Study

This pilot investigation was based on orthodontic records, case records and study models of patients with analogous Class II division 1 malocclusions treated in the University of Manitoba Graduate Orthodontic Clinic (1982-1986) by 3 graduate students under 1 supervisor. Patients received treatment with fixed appliances with a modified Roth prescription. Patients were evaluated at three time periods: T1 = pre-treatment, T2 = post-treatment and T3 = minimum of 3 years post-retention. Twenty cases (10 male, 10 female, average age T1 = 10 years 3 months T2 = 15 years 6 months T3 = 19 years 11 months) of treated Class II div. 1 malocclusions were thus selected based upon the following criteria:

1. the use of non-extraction therapy only, in both arches;

2. availability of complete records (radiographs, models and photographs) including those taken after retention had been completed for a minimum period of 3 years;

3. Caucasian racial background; and

4. treatment undertaken during the adolescent period. Average age of treatment start (T1) = 10 years 3 months. Average age at completion of treatment (T2) = 15 years 5 months). Average age at cessation of retention (T3) = 19 years and 11 months.

The average ages for each assessment time are summarized in Table 3.1.

Table 3.2.1 Average Age of Patients at Times Investigated (Years ± SD)

	MALE	FEMALE
T1	10.6 ± 0.5	9.9 ± 0.6
T2	15.7 ± 0.4	15.3 ± 0.3
T3	19.5 ± 0.3	20.5 ± 0.5

The time periods investigated were chosen as they reflect the dental status of the patient before any treatment (T1), the effect of the treatment on tooth position in the transverse dimension (T2) and the stability of the treatment after the removal of retainers (T3).

Qualitative assessment of these "pilot" cases showed the following features:

- All cases exhibited dental relapse based on the assessment of tooth alignment viewed from the occlusal surfaces of the models (T2-T3).

Of the variables evaluated, the following showed an incidence of relapse greater than 50%:

- alignment of mandibular incisors (82.5%)
- alignment of maxillary incisors (85%)
- maxillary intercanine width (78%)
- mandibular intercanine width (74%)
- maxillary intermolar width (78%)
- mandibular intermolar width (84.5%)

Areas that remained stable (< 50% incidence of relapse from T2-T3) comprised the following:

- maxillary inter first premolar width (24%)
- mandibular inter first premolar width (14%)
- maxillary inter second premolar width (13%)
- mandibular inter second premolar width (8%)

On the basis of the results, the following were identified from the pilot investigation:

- post -treatment relapse;
- post-treatment relapse was mainly defined by incisor alignment, intercanine width and inter first molar width.

3.3 Main Project

Patient Selection

From an initial group of 1380 subjects, 50 (3.6%) cases (26 female, 24 male) of Class II div. 1 malocclusions were selected for this investigation. These were selected from the Burlington Growth Centre Data Bank (no-treatment control group, 13 subjects, limited treatment group, 13 subjects and compound treatment group, 12 subjects) and 12 cases treated in the University of Manitoba Graduate Orthodontic Clinic were selected as the recent treatment group.

Strict criteria were applied to the selection of cases included in this study to reduce variability:

- the availability of complete and accurate pre-treatment, post-treatment and post-retention study models;
- nonextraction, nonsurgical therapy of either limited, compound or recent treatment as previously defined;

- a Class II div. 1 malocclusion with a minimum overjet of 4 mm and minimum half cusp Class II first molar relationship;
- Caucasian racial background; and
- therapy performed prior to growth cessation, confirmed by wrist radiographs (Table 3.3.1).

Table 3.3.1 Mean Age of Subjects (years)

TREATMENT	MALES			FEMALES		
	T1 (Years)	T2 (Years)	T3 (Years)	T1 (Years)	T2 (Years)	T3 (Years)
No Treatment	9.7	16	19.16	9.4	14.3	19.3
Limited	9.3	14.8	18.8	9.4	14.7	19.6
Compound	9.0	14.1	18.7	8.6	15.7	20.0
Recent	14.6	17.3	21.3	7.5	15.0	19.0

Plaster study models of the orthodontically treated sample were then analyzed at the following stages

1. pre-orthodontic treatment (T1);
2. post-treatment (T2); and
3. a minimum of 3 years (range 3.2 years to 5.0 years) post-retention (T3) (Table 3.3.2).

Table 3.3.2 Time Out of Retention (years)

TREATMENT	MALES		FEMALES	
	TIME (Years)	RANGE (Years)	TIME (Years)	RANGE (Years)
No Treatment	3.2	3-4	5	4-6
Limited	4	3-5	4.9	3-7
Compound	4	3-6	3.3	4-6
Recent	4	4	4.2	4-5

The age, gender, race and malocclusion of the control group were then matched to the study group. The control group was derived from the patients evaluated by the Burlington study group who declined treatment. They were analyzed in an analogous manner to the study group to elucidate the dental changes in a non-treated population.

The sample group was divided on the basis of gender and then further subdivided on the type of orthodontic treatment (as previously described) provided (Table 3.3.3).

Table 3.3.3 Distribution of Sample by Gender and Treatment

TREATMENT TYPE	MALE	FEMALE
No Treatment	6	7
* Limited	6	7
** Compound	6	6
*** Recent	6	6

* limited treatment included the use of bite planes, monoblocs, cervical headgear
** compound treatment consisted of full arch banding with a 0 torque and 0 angulation prescription.
*** full arch fixed orthodontic treatment with a modified Roth prescription

The quality of all model records was sufficient to allow accurate recognition of dental landmarks. In addition, all models were trimmed to ensure their bases were parallel to the occlusal surface, defined by the central incisors and first molars.

3.4 Preparation of the Dental Models for Analysis

A standardized setup was then utilized to photograph the occlusal surface of each model individually. This consisted of a Nikon AF camera with a 105 mm macrolens and a Sunflash ring flash supported by a stand set at a distance to ensure a 1:1 image. Colour photographs were taken using Kodak 100 speed film with inclusion of a ruler in each frame to correct for any potential photographic distortion.

The models were positioned with the occlusal plane parallel to the film. Colour photographs of the occlusal views (1:1) for each model, at each time period (T1, T2, and T3) were taken. They were then processed commercially (Ava Photo Labs, Toronto, Ontario) as a single batch to ensure quality consistency and labeled to ensure their identity.

A digital image of each photograph was then captured utilizing a Hewlitt Packard scanner at 100 dpi. The scanner was first calibrated by scanning a millimeter grid and a region of the scanner free from distortion was subsequently identified. Each photograph was placed in this non-distorted area prior to being scanned. After adjustments for contrast discrepancies using the functions provided in the Deskscan® programme, three derived digital images per arch per patient were stored on a 3M formatted disc (IBM compatible). Composite averages of these three images were subsequently used to evaluate the changes in tooth location between the three sets of models for each patient.

3.5 Analysis of Models

A custom-made programme was then created to allow specific datum points on each photograph to be automatically transferred onto a spreadsheet for storage and subsequent mathematical manipulation. The datum points on each set of photographs are defined in Table 3.5.1.

TABLE 3.5.1 Datum Points for Initial Assessment and Determination of Arch Form

1. Mesiobuccal cusp tip of maxillary right first molar
2. Buccal cusp tip of maxillary right second premolar
3. Buccal cusp tip of maxillary right first premolar
4. Cusp tip of maxillary right canine
5. Midpoint on incisal edge of maxillary right lateral incisor
6. Midpoint on incisal edge of maxillary right central incisor
7. Contact point between maxillary central incisors
8. Midpoint on incisal edge of maxillary left central incisor
9. Midpoint of incisal edge of left lateral incisor
10. Cusp tip of left canine
11. Buccal cusp tip of maxillary left first premolar
12. Buccal cusp tip of maxillary left second premolar
13. Mesiobuccal cusp tip of left maxillary first molar
14. Mesiobuccal cusp tip of mandibular left first molar
15. Buccal cusp tip of mandibular left second premolar
16. Buccal tip of mandibular left first premolar
17. Cusp tip of mandibular left canine
18. Midpoint of mandibular left lateral incisor
19. Midpoint of incisal edge of mandibular left central incisor
20. Contact point between mandibular central incisors
21. Midpoint of incisal edge of mandibular right central incisor
22. Midpoint of incisal edge of mandibular right lateral incisor
23. Cusp tip of mandibular right canine
24. Buccal cusp tip of mandibular right first premolar
25. Buccal cusp tip of mandibular right second premolar

25\. Mesiobuccal cusp tip of mandibular right first molaR

Datum Points for Incisal Alignment

1. Mesial contact point of right canine
2. Distal contact point of right lateral incisor
3. Mesial contact point of right lateral incisor
4. Distal contact point of right central incisor
5. Mesial contact point of right central incisor
6. Mesial contact point of left central incisor
7. Distal contact point of left central incisor
8. Mesial contact point of left lateral incisor
9. Distal contact point of left lateral incisor
10. Mesial contact point of left canine

Datum Points for Intercanine Width

1. Cusp tip of right canine
2. Cingulum of right canine
3. Cingulum of left canine
4. Cusp tip of left canine

Datum Points for Intermolar Width

1. Mesiobuccal cusp of right first molar
2. Distobuccal cusp of right first molar
3. Mesiobuccal cusp of left first molar
4. Distobuccal cusp of left first molar

The pixel values for the x and y coordinates of each of these points were then zeroed about a centre point. As previously described (Lundstrom, 1969) the maxillary skeletal midline was defined by a line bisecting the palate through the fovae palatini and rugae. This line was then transferred to the mandibular arch, through superimposition of interarch contact points. To correct for potential distortion, two points on the scale incorporated in each photograph were also digitized. The number of pixels per cm could be calculated to convert the datum points into "real" numbers. Repeat digitization of the photographs from five patients showed measurement error of less than 2%. This proved to be statistically insignificant from analysis of variance ($p < 0.05$) compared with the variance among subjects.

3.6 Analysis of Data

The data were analyzed in several ways:

- **Identification of areas of maximum dental arch change and their direction**

The series of digitized points on each model were standardized to ensure that the predefined points were analogous for each tooth. This was done through repeat digitization of each model at each time period on three different occasions. The results showed an accuracy to 0.01 mm. Subsequent measurements were then taken to correspond to the area(s) showing a greater than 50% incidence of change through treatment and post retention as defined in the pilot study. As illustrated in Figures A, B, and C the following measurements were recorded on each photograph:

i) intermolar width

ii) intercanine width

iii) incisor alignment

To analyze the effect of treatment, and relapse in the post-retention period (T2 - T3) on changes in intertooth widths, these parameters were computed independently for both the maxillary and mandibular dentition at all three stages of treatment. In addition, absolute values, changes in values, and the direction of

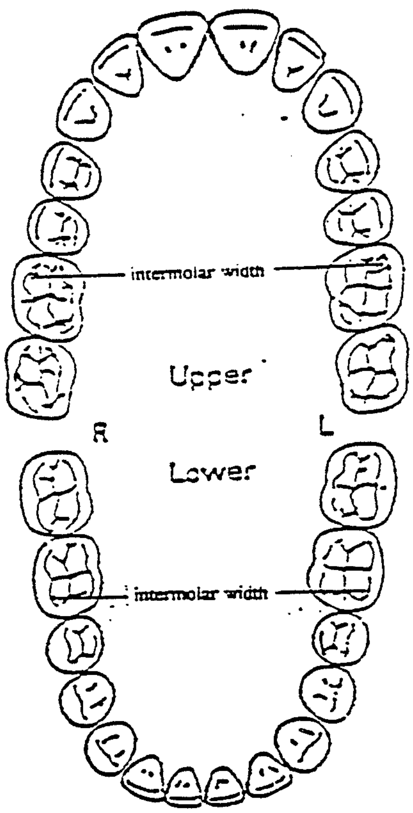


Figure 3.6A

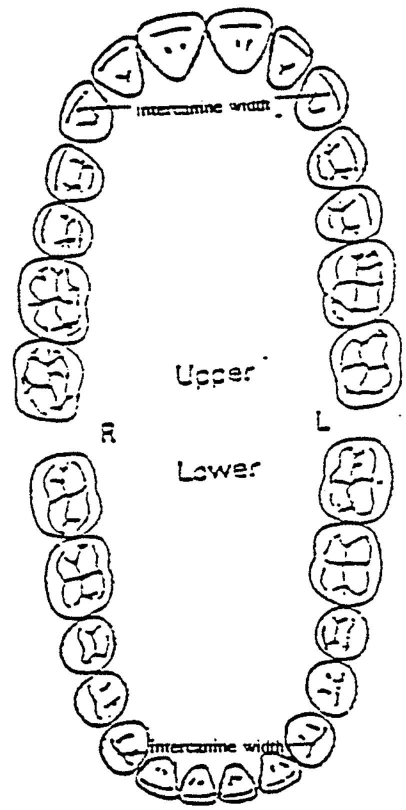


Figure 3.6B

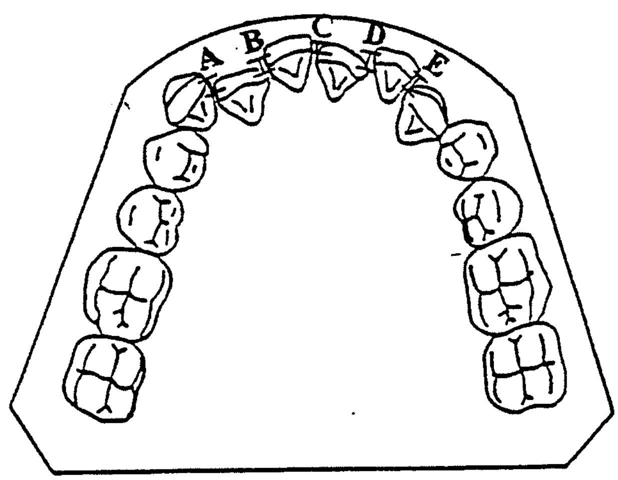


Figure 3.6C (Little's Irregularity Index)
A+B+C+D+E = Incisor Irregularity Index

change were recorded for each patient. They were then referenced with the type of treatment provided. These changes were also compared with the changes recorded in the control (untreated) group of patients.

- **Definition of Changes in Dental Arch Form**

The form of the dental arches at the three time periods was defined by a mathematical model based on the curves of varying power computed to fit the original series of digitized datum points. Points corresponding to the medial raphe and palatal rugae were also digitized to allow for superimposition of the generated curves at the three time periods investigated. Mathematical curves ranging from a parabola to a polynomial equation were then "curve fitted" to the data based on the technique of Sampson.

The size and shape of the human dental arches has been studied for over a century (Bonwill, 1884-5; Black, 1902). However, the studies have been handicapped by the lack of precise geometrical methods for describing or modeling biological shape and by the lack of a statistical model permitting the investigation of concepts of "average shape" and variation among shapes in populations. Recent work in the field of morphometrics - the measurement of shape, its variation and change - provides valuable new tools for the discussion of biological shapes (Blum 1973; 1979; Bookstein, 1978; 1979). Based on the work of Sampson (1981), which allows modification of his algorithm to model any shape of arch as well as providing a framework for analysis of populations of shapes that can be modeled with arcs of conic sections, a computer-generated arch form was made for each dental arch photograph using a least squares algorithm to fit conic sections to their associated sets of datum points.

Eccentricity was defined by the shape of the conic sections. Their eccentricity *(e)* is a positive constant determined by a ratio inherent to the conic sections defined by the distance between any point on the curve and a fixed line called the **directrix** (Hrdlicka, 1916). A circle has an $e = 0$, an ellipse has $0 < e < 1$, a parabola has $e = 1$, and a hyperbola has an $e > 1$. As an arch becomes more rounded, the eccentricity diminishes, whereas when the arch is tapered, the eccentricity increases. These delineations of e values are mathematically proven but if different values were chosen our results would be altered statistically.

Based upon consultation with the Biostatistics department at the University of Manitoba (Dr. T Hassard and Mrs. Cheang), these data were then subjected to repeated measures ANOVA analyses, with further follow-up analyses including Students' t-test, Least Square Differences, and/or Tukey's Analysis) where warranted.

3.7 Error of the Method

The error of the method was evaluated by marking, mounting and digitizing 10 sets of models on three separate occasions and comparing the results for accuracy. The linear distances were accurate to within $\pm$ 0.1 mm with 95% certainty. In addition, the maxillary arches of five patients and the mandibular arches of another group of five patients were randomly selected and redigitized two weeks after the initial digitization process. The eccentricity values determined were within 0.01 with a 95% certainty. The specific arch parameters, tooth orientation, and arch forms were defined on three separate occasions where their subsequent analyses confirmed that measurement or digitization errors were unlikely to have contributed to the changes identified by this analysis.

RESULTS

The aim of this section is:

- to assess the efficacy as judged by the relapse of three treatment modalities, seen post-retention, measured from the dental study models);
- to assess the stability of the treatment(s) outcomes;
- to compare these changes with those defined in the untreated population
- to evaluate stability of tooth position as a measure of the quality of orthodontic care provided.

These results are examined under the following headings to simplify their interpretation:

- incidence of relapse
- treatment modalities
- general interactions
- incisor irregularity
- intercanine width
- intermolar width
- changes in arch form

4.1 Incidence of Relapse

All intertooth widths were measured and the percentage of those that showed relapse were recorded. Information on the areas showing > 50% incidence of change through treatment (T1 - T2) and post-retention (T2 - T3) is summarized in Table 4.1.1.

Table 4.1.1 Incidence of Change in the Dimensions Assessed in the Treated Groups

AREA	MALES		FEMALES	
	Maxilla	Mandible	Maxilla	Mandible
Incisor Alignment *	83%	92%	85%	73%
Intercanine Width *	83%	75%	73%	73%
Inter First Premolar Width	11%	18%	22%	32%
Inter Second Premolar Width	9%	12%	16%	21%
Inter Molar Width *	71%	92%	85%	77%

* areas chosen to assess

The areas chosen for measurement in the study (those showing >50% incidence of relapse) were: incisor alignment, intercanine width and intermolar width. These data showed that although males differed from females in the incidence of relapse in the zones measured and the maxilla differed from the mandible in the incidence of relapse in each zone measured, there was no apparent pattern or statistically significant difference ($p < 0.05$).

4.2 Treatment modalities

Repeated measures analysis of variance was performed on the data summarized in Tables 4.2.1 and 4.2.2.

Table 4.2.1 Summary of Dental Arch Changes in Male Patients (mm)

MALES	MAXILLA												MANDIBLE											
	T2-T1						T3-T2						T2-T1						T3-T2					
	Molar		Canine		Incisor		Molar		Canine		Incisor		Molar		Canine		Incisor		Molar		Canine		Incisor	
Patient	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec
No treatment																								
1	2.0			1.3		2.0		NC		0.7	2.0		NC		NC			2.6		0.6	NC		1.3	
2	0.7			2.7		2.6	NC		0.3		NC		2.7			0.7		0.3	0.6		NC			1.0
3	2.0		0.7			3.0	NC		NC		0.7		1.3			2.7		1.4		0.7	NC		0.3	
4	NC		NC			3.3		0.7		0.7	2.0		2.6			1.4		NC		1.3		0.6	1.3	
5	1.4		0.4			5.0	NC			0.7	1.3		0.7		2.0		1.3			0.7		1.3	0.7	
6		2.0	3.0			5.0	2.7			1.0	1.0		0.7			0.7		0.7		0.7		0.6		0.7
Limited Treatment																								
7	5.0		NC			5.0	NC		NC		NC		2.1			0.7		NC	1.3			1.4	0.7	
8	4.4		4.3			4.6		0.7		1.3		1.0	2.6		NC			0.7		0.6	NC		1.3	
9	2.6		0.6			3.3		0.3		0.6	NC		0.6			1.3		2.6		0.6		0.7	2.0	
10	0.7		2.6		0.4			0.6		1.3		1.0	NC			0.6	NC		1.0		0.3		1.0	
11		6.0		0.3		2.0		1.3		0.7		0.6		2.7		1.3	NC			0.7		0.7	1.4	
12	1.0		NC			1.0	NC			1.0	0.5		1.5		NC			1.5	0.5		NC		0.5	
Compound Treatment																								
13	0.7		0.3		0.6		1.3			1.3		2.0		0.7		0.7	0.6		NC			2.0	NC	
14	2.0		NC			1.0		1.4		1.3		1.0		2.0		0.6	2.0			0.7		0.7	0.6	
15	NC		5.3			0.7		0.6		2.3	1.3		0.7			0.3		0.7	2.0		0.3		NC	
16	2.0			1.4		2.7	NC			0.6		1.7	NC		2.3			0.4		1.7		1.3	1.0	
17	0.7			0.4	NC			0.6		1.4	1.3			1.3		2.0	1.3		NC			1.3	4.7	
18	NC		4.0			1.7		0.7		1.4		0.3	0.6		NC		NC			0.6		0.7		2.6
Recent Treatment																								
19		2.0		4.0		2.6		1.7		0.6	1.0			2.0		2.0		2.6	0.7		2.0		NC	
20		1.3		0.7		4.6	1.3			1.0	1.0			1.3		1.3		4.6	1.3		1.0		1.0	
21		0.7	NC			2.0	0.7		NC		NC			0.7	NC			2.0	2.0		1.3		NC	
22		0.7		0.7		4.0	2.0			1.4	2.0			0.7		1.4		4.0	2.0		1.4		2.0	
23	2.0		NC			6.3		0.3	NC		1.3		2.0		NC			6.3	7.0		NC		1.3	
24	2.0		2.0			6.6		1.4		1.4	4.0		2.0		2.0			6.6		1.4		1.4	4.0	

dec = decrease in dimension
inc = increase in dimension
NC = no change in dimension

Table 4.2.2 Summary of Dental Arch Changes in Female Patients (mm)

FEMALES	MAXILLA												MANDIBLE											
	T2-T1						T3-T2						T2-T1						T3-T2					
	Molar		Canine		Incisor		Molar		Canine		Incisor		Molar		Canine		Incisor		Molar		Canine		Incisor	
Patient	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec
No Treatment																								
25		2.7	NC			4.0		6.0		2.0	1.3		NC		NC		0.7		NC			0.7	2.0	
26	2.0		0.7		0.6		2.0			1.4	0.7		1.3			0.7		1.3	0.6			0.6	2.0	
27	0.7		1.3			0.6		0.3	0.7		2.0			1.4		1.3		0.7		0.7	NC		1.4	
28	3.3		2.3			4.6	0.7		0.7		NC			1.3	NC		NC			2.0		0.7	1.3	
29		0.6	NC		NC		2.0		1.3		0.3		2.6		0.7		2.0			0.7		1.3	2.0	
30	2.0		2.0			0.7	1.0		NC			2.0		0.7	0.6			1.3	4.3		0.7			0.6
31	1.3			1.0		4.6		0.7	0.6		NC		1.0		0.6			2.7	NC		NC		NC	
Limited Treatment																								
32		2.0	NC			4.0	2.0		2.0		NC		NC		2.3			2.7	NC		1.0		NC	
33	2.6		1.4			0.4		2.0		0.7	1.7		1.3		0.7			1.0	1.3		NC		1.3	
34	2.6		0.7		0.6			2.0		0.7	NC		NC		NC		2.7		NC		0.7		1.3	
35	1.4		2.0			0.7	1.0			2.0	NC		NC		0.7			2.0	NC			1.7	NC	
36	4.7		NC			2.0		2.0	NC		2.3		4.0		NC		2.7		0.7		NC		0.6	
37		0.7	NC			1.3	2.0			2.0	2.6			2.0	0.7			1.0		2.7	1.0		2.3	
38	0.4		NC			3.3	0.4		NC		1.3			0.7	NC			1.3		0.7	NC		1.0	
Compound Treatment																								
39	2.7		0.7		1.6		NC			1.4		2.0	4.0		0.7		NC		NC		0.3		NC	
40	1.0		2.0			3.0	NC		2.0		1.0			1.0		2.0		4.0		1.0		0.6		0.6
41	NC			2.7	2.0			1.4		0.7		2.6	7.3		NC		5.3			0.7		0.7	NC	
42	4.7		NC			4.3		1.4		0.7		2.3	2.7		NC			2.0		2.7		0.3	2.6	
43	2.7		3.3			2.3		0.7	0.7		1.6		NC		0.7		1.3			1.3		1.3	2.0	
44	2.7		0.7		0.6			2.0	NC			0.6	0.6			0.7	1.3		0.7		NC		NC	
Recent Treatment																								
45	3.4		2.0			21		2.0	0.6		4.0		0.7			4.3		5.6	NC			1.3		0.6
46	0.7			0.6		17.3	1.3		NC		1.0		3.3		0.7			8.1		2.0		0.7	2.1	
47		0.7	2.6			4.0	NC			2.0	7.3		0.4		NC		NC			2.0		NC	1.0	
48	3.3			0.3		10.6		3.3	NC		2.0		NC		1.6			1.0		2.0		0.6	2.0	
49	1.4		3.3			7.3	0.6			0.7	1.0		2.0		2.4			6.6		3.4		1.0	NC	
50		2.0		1.0		6.0	6.6		1.0		4.0			6.0	2.0			4.0		0.4		0.7	0.5	

dec = decrease in dimension
inc = increase in dimension
NC = no change

These data showed the following:

- a statistically significant difference ($p < 0.05$) from the post-treatment to post-retention stages (T2 - T3) in the incidence of relapse in the incisor alignment, intercanine and intermolar width parameters relative to the control group (no treatment) and to the recent treatment group. The recent treatment group showed the greatest changes post-retention (Tables 4.2.3 and 4.2.4).
- a statistically significant difference ($p < 0.05$) from the post-treatment to post-retention stages (T2 - T3) in the incidence of relapse in the parameters of incisor alignment, intercanine width, intermolar width when comparing the limited treatment group with the recent treatment group. The recent treatment showed more changes post-retention (Tables 4.2.3 and 4.2.4).

4.2.3 ANOVA for Differences in Treatment Type and the Incidence of Relapse

SOURCE	SS	DF	MS	F
Between	1.764	3	0.588	2.96*
Within	8.7427	44	0.1986	
Total	10.5067	47		

*significant at p<0.05

4.2.4 Least Square Difference For Treatment Modalities

	No Treatment	Limited	Compound	Recent
No Treatment	-	0.8152	0.1549	0.0052*
Limited	0.8152	-	0.2301	0.0095*
Compound	0.1549	0.2301	-	0.1479
Recent	0.0052	0.0095	0.1479	-

*significant at p<0.05

These results therefore showed no statistically significant differences in the amount of change in these parameters between the untreated control, limited treatment and compound groups. However, all three differed from the data from the recent treatment group, i.e., this latter group exhibited the greatest amount of post-retention relapse.

4.3 General Interactions

General trends in the incidence and amount of change seen in the treated populations were evaluated from repeated measures ANOVA analysis, as summarized in Table 4.3.1.

Table 4.3.1 Repeated Measures ANOVA Analysis for General Trends (F Values)

SOURCE	TYPE III SUM OF SQUARES	MEAN SQUARE VALUE	F VALUE
Treatment	6×10^{-8}	3×10^{-8}	2.00
Gender	1×10^{-8}	7×10^{-8}	0.14
Arch	1×10^{-8}	6×10^{-8}	0.16
Zone	2×10^{-8}	6×10^{-8}	0.33

The results indicated:

- no significant differences in the incidence of relapse between the maxillary and the mandibular arches or by gender;
- no significant interactions were noted between the incidence of relapse and incisor alignment, intercanine width or intermolar width when repeated measures were subjected to ANOVA.

4.4 Incisor Irregularity

The average values of incisor irregularity calculated by Little's method (Little, 1975) are summarized in Table 4.4.1. In this instance, incisor irregularity was defined as the sum of the distance between the contact points from the mesial contact point of one canine to the mesial contact point of the other canine.

Table 4.4.1 Average Value for Incisor Irregularity (mean ± SD in mm)

		MANDIBLE			MAXILLA		
		T1	T2	T3	T1	T2	T3
MALE	Limited	2.2±0.90	1.8±1.30	2.9±1.14	5.8±2.14	3.2±1.56	2.8±1.21
	Compound	3.1±0.92	3.6±1.23	3.9±3.03	5.8±1.91	5.1±1.50	5.0±2.04
	Recent	4.4±1.61	0.2±0.37	1.6±1.24	7.9±2.36	0	2.3±1.03
	Control	2.8±1.17	2.8±1.45	3.3±1.87	6.1±1.27	2.6±0.90	3.3±1.89
FEMALE	Limited	2.7±1.83	2.6±2.61	3.5±2.78	4.4±1.51	2.7±1.02	3.8+1.60
	Compound	2.8±1.42	2.9±2.42	3.6±2.61	3.9±1.49	3.0±2.81	3.9±3.34
	Recent	3.5±3.48	1.2±2.66	2.0±2.00	11.0±6.8	0	3.2±2.42
	Control	3.4±3.15	3.0±2.27	4.1±1.75	6.4±1.75	4.4±1.05	4.3±1.01

T1 = pretreatment
T2 = post-treatment
T3 = post-retention

Results for T2 and T3 were compared with previous values (T1) and expressed as a percentage change from that previous measurement. These are summarized in Table 4.4.2.

Table 4.4.2 Percentage Change in Incisor Irregularity

		MANDIBLE		MAXILLA	
		T2	T3	T2	T3
MALE	Limited	-1.2	61.1	-44.8	34.6
	Compound	16	83.3	-12.1	3.6
	Recent	-95	700	-100	66.6
	Control	0	57.4	-57.4	36.7
FEMALE	Limited	-3.7	12.5	-38.6	40.7
	Compound	3.5	1.9	-23.1	38.0
	Recent	-65.7	57.1	-100	33.3
	Control	-11.8	26.9	-31/1	2.0

T1 -pretreatment
T2-post-treatment
T3-post-retention

In summary, therefore, these data showed a decrease in index scores through treatment (T2 - T1), but an increase in the post retention phase (T3- T2).

4.5 Intercanine Width

Calculated as the distance between canine cusp tips the intercanine widths, the comparisons are summarized in Table 4.5.1.

Table 4.5.1 Average Value for Intercanine Width (mean ±SD in mm)

		MANDIBLE			MAXILLA		
		T1	T2	T3	T1	T2	T3
MALE	Limited	25.7±1.17	25.0±0.98	24.6±0.68	32.9±2.38	34.0±0.98	33.3±1.26
	Compound	25.9±1.73	25.7±2.34	24.8±2.54	33.4±2.06	34.4±2.54	33.1±2.36
	Recent	25.9±1.22	25.1±1.34	25.8±1.17	33.8±2.43	33.9±0.67	34.2±1.25
	Control	28.2±1.33	27.6±0.84	27.2±0.72	35.6±2.46	37.2±1.73	36.8±1.86
FEMALE	Limited	25.4±1.26	25.8+1.18	25.5±1.42	34.1±1.97	34.6±2.10	34.9±1.38
	Compound	23.4±2.59	23.0±1.58	22.9±1.93	30.8±2.04	31.4±2.58	32.9±2.66
	Recent	23.5±2.79	23.9±1.39	23.3±1.72	30.6±1.62	31.5+2.87	31.2±2.23
	Control	25.4±1.98	25.4±2.13	24.8±2.74	34.3±2.39	35.0±2.28	35.1±2.61

T1 = pretreatment
T2 = post-treatment
T3 = post-retention

Results for T2 and T3 were compared with previous values (T1) and expressed as a percentage change from that previous measurement. These are summarized in Table 4.5.2.

Table 4.5.2 Percentage Change in Intercanine Width

		MANDIBLE		MAXILLA	
		T2	T3	T2	T3
MALE	Limited	-2.7	-1.6	2.7	-2.1
	Compound	-0.7	-3.5	2.9	-3.8
	Recent	-3.1`	2.8	0.3	0.9
	Control	-2.1	-1.4	4.5	-1.1
FEMALE	Limited	-1.6	-1.2	1.5	0.9
	Compound	-1.7	-0.4	1.9	4.8
	Recent	1.7	-2.5	2.9	-0.9
	Control	0	-2.4	2.0	0.3

T1 - pretreatment
T2-post-treatment
T3-post-retention

Overall intercanine mandibular widths decreased through treatment (T1 - T2). Overall a decrease was noted in the post-treatment to post-retention (T2 - T3) period.

4.6 Intermolar Widths

Calculated as the distance between the mesiobuccal cusps of first molars, these values are summarized in Table 4.6.1.

Table 4.6.1 Average Value for Intermolar Width (mean ± SD in mm)

		MANDIBLE			MAXILLA		
		T1	T2	T3	T1	T2	T3
MALE	Limited	42.6±2.38	43.3±3.74	42.8±4.00	50.1±2.79	51.5±3.56	51.0±3.95
	Compound	43.9±1.97	43.5±2.17	43.5±2.29	49.5±1.77	50.2±2.96	49.3±3.29
	Recent	44.9±1.83	44.8±1.32	45.5±2.10	49.3±3.96	50.8±1.61	51.1±2.10
	Control	44.6±3.45	45.9±3.22	45.4±3.14	52.7±3.80	54.4±3.91	53.8±3.04
FEMALE	Limited	43.9±2.21	43.9±2.48	43.3±2.69	49.9±2.66	51.3±2.96	51.1±2.95
	Compound	40.3±2.21	42.6±1.88	42.1±1.85	47.1±2.36	49.4±2.74	48.1±1.86
	Recent	40.9±2.57	41.9±2.52	40.3±1.78	46.5±2.53	47.3±3.51	46.9±2.49
	Control	43.9±2.85	44.1±3.14	44.1±4.79	50.5±2.89	51.5±4.35	51.5±4.31

T1 = pretreatment
T2 = post treatment
T3 = post retention

Results for T2 and T3 were compared with previous values (T1) and expressed as a percentage change from that previous measurement. These are summarized in Table 4.6.2.

Table 4.6.2 Percentage Change in Intermolar Width (%)

		MANDIBLE		MAXILLA	
		T2	T3	T2	T3
MALE	Limited	1.6	-1.1	2.8	-0/7
	Compound	-0.9	0	1.9	-1.7
	Recent	-0.2	1.5	1.8	0/6
	Control	2.9	-1.1	3.2	-1.1
FEMALE	Limited	0	-1.4	2.8	-0.4
	Compound	5.7	-1.1	4.8	-2.6
	Recent	2.7	-3.8	1.7	-0.8
	Control	0.5	0	11.9	0

T1 -pretreatment
T2-post-treatment
T3-post-retention

Overall intermolar widths increased through treatment (T1 - T2). Overall a decrease was noted in the post-treatment to post-retention (T2 - T3) period. None of the results were, however, statistically significantly different ($p < 0.05$) on comparison between treatment modalities, gender or arch. These results therefore indicated that this dimension was relatively stable post-retention.

4.7 Arch Form Assessment

Based on the work of Sampson (1981) a computer-generated least squares algorithm generated an arch form for each dental arch photograph, and fit conic sections to their associated sets of datum points. The shape of the sections is defined by arch form eccentricity.

As summarized in Tables 4.7.1 and 4.7.2, the results showed that 89% of the pre-treatment and post-retention dental arches were best described by ellipses, with the eccentricity ranging from $e = 0.60$ to 0.87. The remaining 11% of the arches were best defined by parabolas. By contrast, all the end of treatment arches were best described by ellipses.

No statistical difference was found when comparing pre-treatment, post-treatment and post-retention arch forms. Descriptively it can be said that all arch forms became more rounded through treatment (an increase at the intercanine area) and that this change was not held post-retention.

Table 4.7.1 Male Patients' Eccentricity Values (e)

	MAXILLA			MANDIBLE		
Patient	T1	T2	T3	T1	T2	T3
No treatment						
1	0.60	0.60	0.60	0.61	0.62	0.62
2	0.62	0.63	0.63	0.66	0.66	0.65
3	0.68	0.69	0.69	0.71	0.72	0.71
4	0.69	0.71	0.71	0.72	0.73	0.73
5	0.81	0.65	0.81	0.77	0.67	0.75
6	0.83	0.85	0.84	1.18	0.87	1.17
Limited						
7	0.74	0.76	0.74	0.81	0.79	0.80
8	1.10	0.87	1.13	1.12	0.85	1.09
9	0.78	0.78	0.79	0.75	0.71	0.74
10	0.83	0.79	0.84	0.74	0.68	0.73
11	0.75	0.67	0.74	0.66	0.63	0.65
12	0.64	0.63	0.65	0.62	0.60	0.61
Compound						
13	0.81	0.65	0.77	0.74	0.71	0.73
14	0.80	0.78	0.80	0.78	0.75	0.78
15	0.69	0.67	0.69	0.75	0.73	0.76
16	0.85	0.85	0.85	0.73	0.71	0.74
17	0.67	0.65	0.67	0.71	0.69	0.73
18	0.68	0.66	0.68	0.70	0.68	0.70
Recent						
19	0.73	0.71	0.74	0.76	0.73	0.75
20	0.85	0.83	0.85	0.70	0.68	0.71
21	0.83	0.81	1.01	0.70	0.69	0.69
22	0.78	0.76	0.78	0.79	0.76	0.76
23	0.80	0.78	0.80	0.74	0.70	0.71
24	0.69	0.67	0.70	1.02	0.86	1.01

Table 4.7.2 Female Patients' Eccentricity Values (e)

	MAXILLA			MANDIBLE		
Patient	T1	T2	T3	T1	T2	T3
No treatment						
25	0.76	0.74	0.75	0.78	0.76	0.78
26	0.69	0.67	0.68	0.71	0.69	0.69
27	0.73	0.73	0.71	0.75	0.75	0.75
28	0.68	0.68	0.68	0.73	0.71	0.75
29	0.71	0.71	0.70	0.74	0.73	0.76
30	0.73	0.74	0.71	0.73	0.74	0.75
Limited						
31	0.78	0.80	0.76	0.85	0.84	0.84
32	0.73	0.69	0.72	0.71	0.72	0.73
33	0.80	0.70	0.77	0.77	0.71	0.75
34	0.84	0.81	0.83	0.85	0.84	0.84
35	0.77	0.75	0.75	0.77	0.77	0.78
36	0.76	0.74	0.76	0.75	0.76	0.76
Compound						
37	0.81	0.79	0.80	0.80	0.78	0.79
38	0.85	0.83	0.84	0.86	0.84	0.83
39	0.70	0.68	0.70	0.74	0.70	0.74
40	0.77	0.75	0.77	0.77	0.76	0.77
41	0.68	0.67	0.68	0.70	0.68	0.69
42	0.74	0.73	0.75	0.77	0.75	0.77
43	0.83	0.80	0.83	0.80	0.81	0.80
Recent						
44	0.83	0.67	0.83	0.79	0.60	0.76
45	1.01	0.85	1.15	0.85	0.85	0.84
46	0.69	0.68	0.68	0.69	0.67	0.68
47	0.67	0.64	0.68	0.70	0.67	0.69
48	0.73	0.67	0.73	0.70	0.68	0.69
49	0.75	0.74	0.74	0.78	0.76	0.77
50	0.77	0.73	0.76	0.76	0.74	0.74

Sample Cases

To illustrate the changes seen in the three treatment modalities as well as those seen in the untreated control group, a sample case from each of the four groups will be presented.

Example 1: No Treatment

This patient showed a marked broadening of the maxillary arch as defined by the eccentricity (pre-treatment e = 0.81, post-treatment e = 0.65 and post-retention e = 0.81). Similar changes in arch form were also evident in the mandibular arch (pre-treatment e = 0.77, post-treatment e = 0.67 and post-retention e = 0.75).

Example 2: Limited Treatment

This patient received treatment in the maxillary arch consisting of a removable retainer as well as cervical headgear and a removable appliance for the mandibular arch. The results showed broadening of the maxillary arch as defined by the eccentricity (pre-treatment e = 0.80, post-treatment e= 0.70 and post-retention e = 0.77). Similar changes in arch form were also seen in the mandibular arch (pre-treatment e = 0.77, post- treatment e = 0.71 and post-retention e = 0.75).

Example 3: Compound Treatment

This patient received treatment consisting of full banded maxillary and mandibular fixed appliances with edgewise technique. The results showed a marked broadening of the maxillary arch as defined by the eccentricity (pre-treatment e = 0.85, post -treatment e = 0.65 and post-retention e = 0.77). Similar changes were also evident in the mandibular arch (pre-treatment e = 0.74 post-treatment e = 0.71 and post-retention e = 0.73).

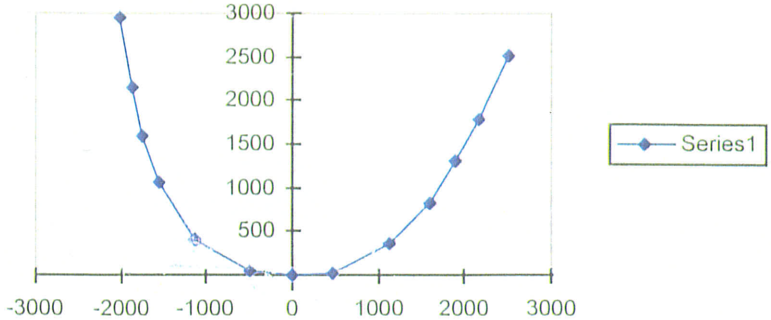
Example 4 : Recent Treatment

This patient received full fixed maxillary and mandibular orthodontic treatment using a straightwire appliance with a modified Roth prescription. The data showed a marked broadening of the maxillary arch as defined by the eccentricity (pre-treatment e = 0.83, post-treatment e = 0.67, and post-retention e = 0.83), whereas similar changes in the mandibular arch (pre-treatment e = 0.79, post-treatment e = 0.60, and post-retention e = 0.76) were also noticed i.e., none of the treatment effects were held post-retention.

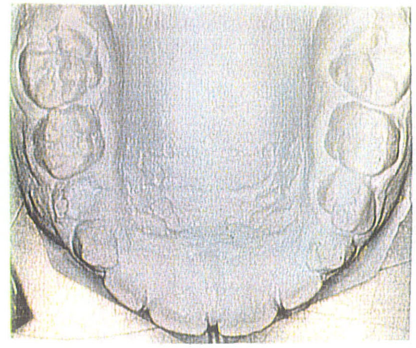
In general, therefore, relapses were evident in all cases during the post-retention period.

Figure 4.1A Changes in Maxillary Arch Form

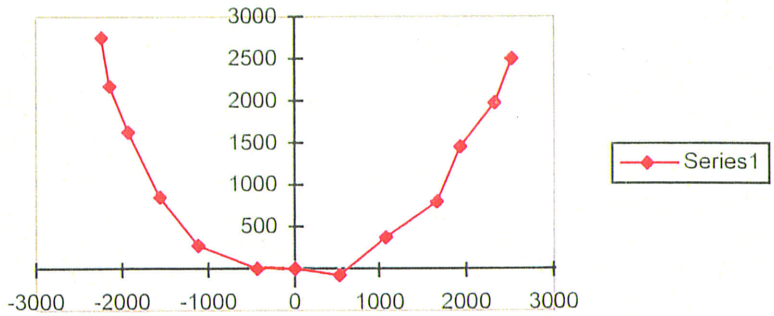
Pre-treatment



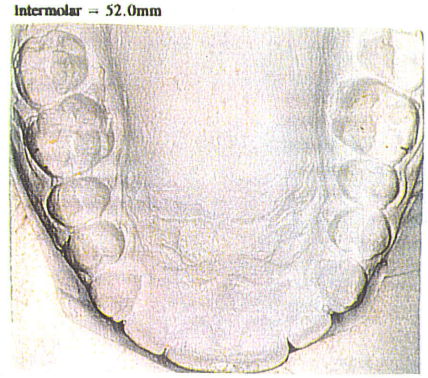
AGE = 9 years
II = 6mm
Intercanine = 34.0mm e=0.81
Intermolar = 48.6mm



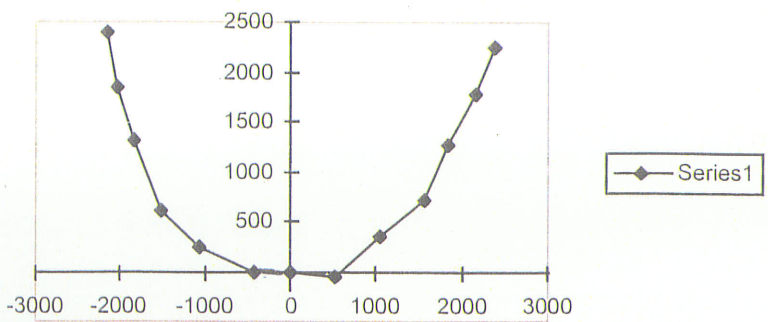
Post-treatment



AGE = 16 years
II = 1mm
Intercanine = 38.0mm e=0.65
Intermolar = 52.0mm



Post-retention



AGE = 21 years
II = 2.3mm
Intercanine = 37.0mm e=0.81
Intermolar = 52.0mm

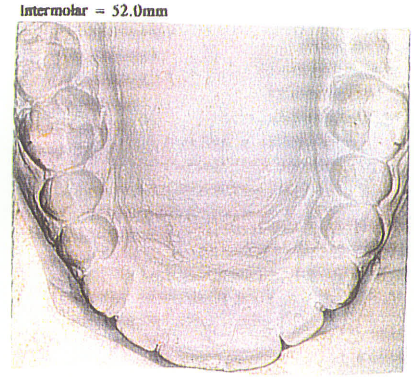
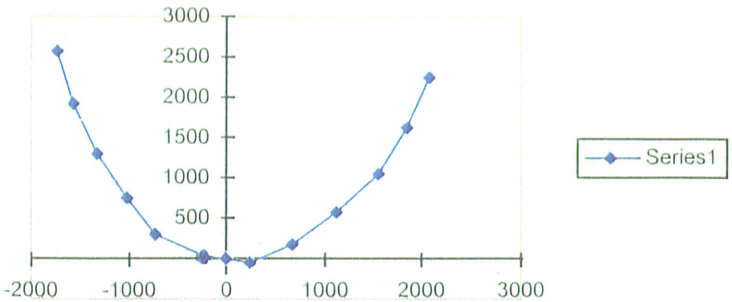
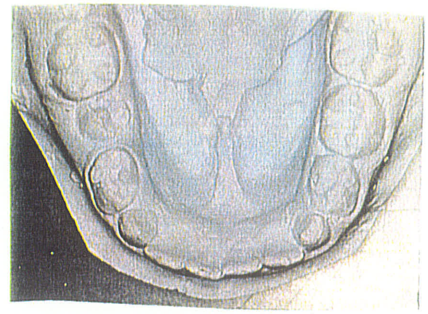


Figure 4.1B Changes in Mandibular Arch Form

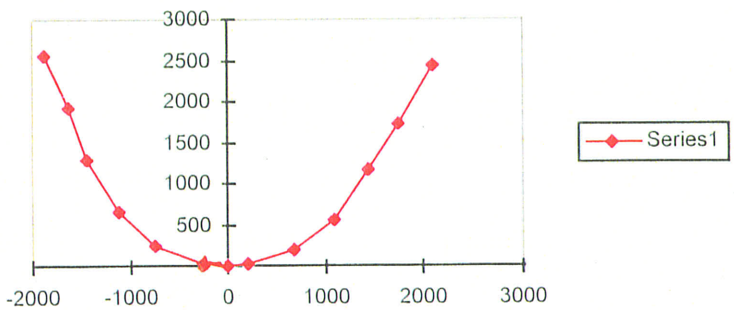
Pre-treatment



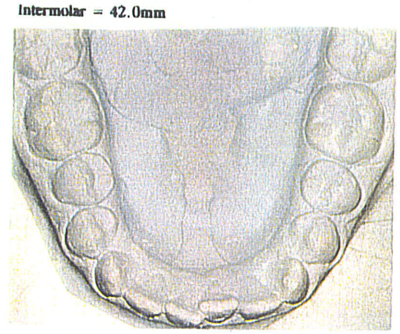
AGE = 9 years
II = 2mm
Intercanine = 26.6mm e=0.77
Intermolar = 41.3mm



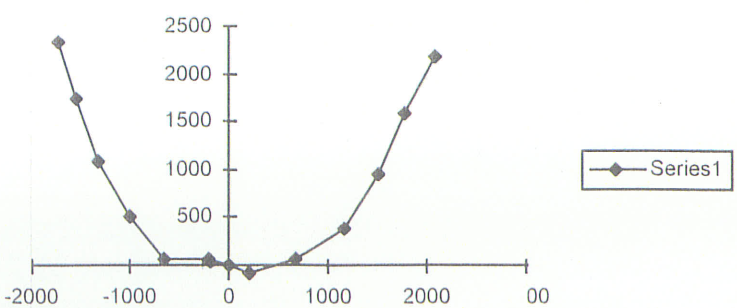
Post-treatment



AGE = 16 years
II = 3.3mm
Intercanine = 28.6mm e=0.67
Intermolar = 42.0mm



Post-retention



AGE = 21 years
II = 4mm
Intercanine = 27.3mm e=0.75
Intermolar = 41.3mm

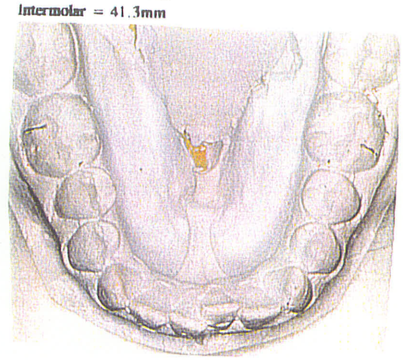
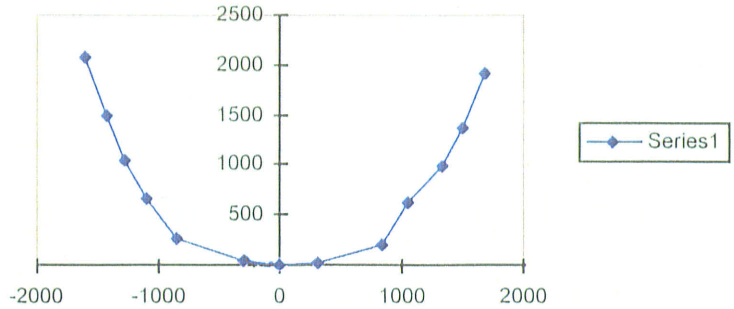
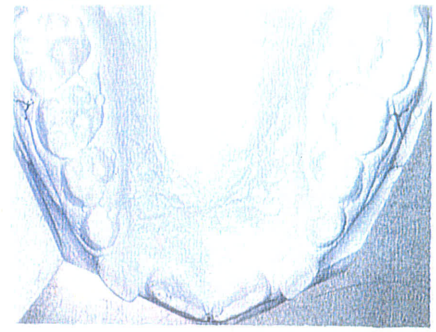


Figure 4.2A Changes in Maxillary Arch Form

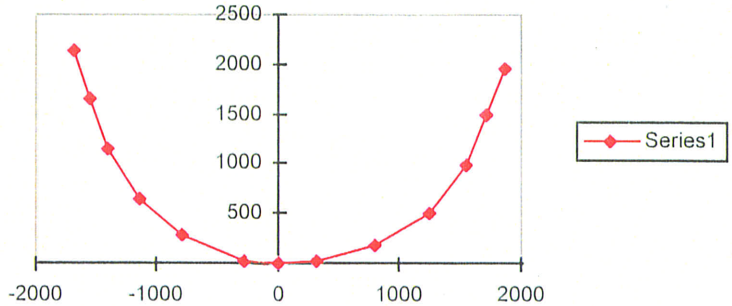
Pre-treatment



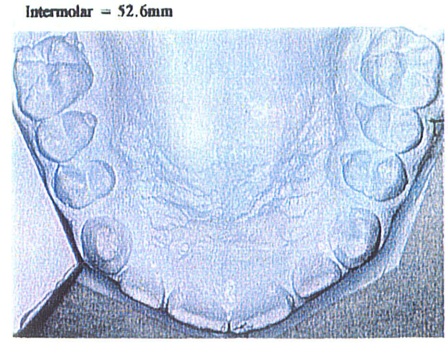
AGE = 8 years
II = 5mm
Intercanine = 34.6mm e=0.80
Intermolar = 50.0mm



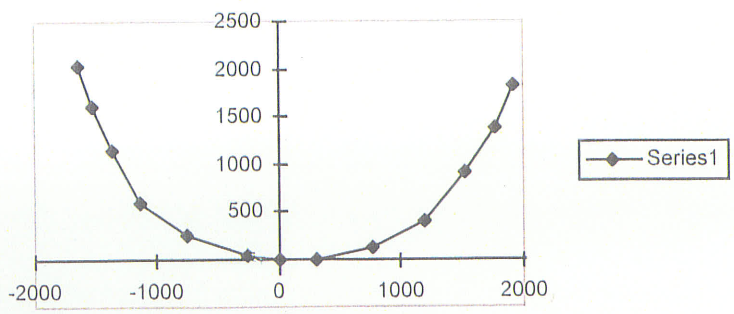
Post-treatment



AGE = 14 years
II = 3mm
Intercanine = 36.0mm e=0.70
Intermolar = 52.6mm



Post-retention



AGE = 20 years
II = 5.3mm
Intercanine = 35.3mm e=0.77
Intermolar = 50.6mm

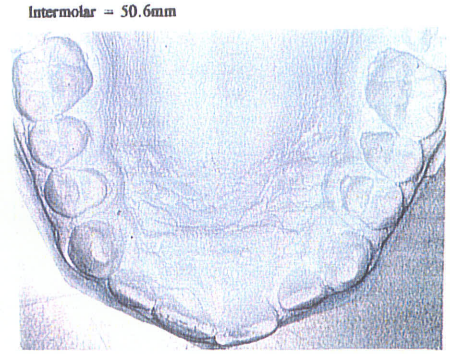
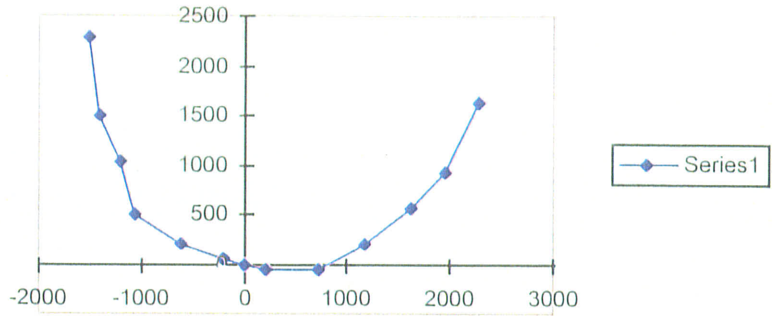


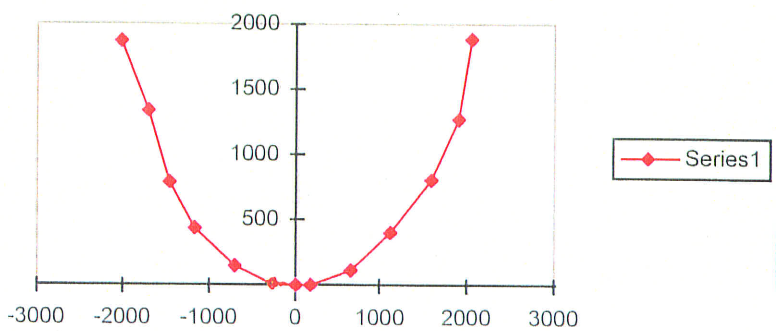
Figure 4.2 B Changes in Mandibular Arch Form

Pre-treatment

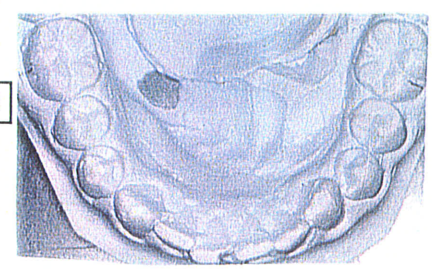


AGE = 8 years
II = 2mm
Intercanine = 26.6mm e=0.77
Intermolar = 44.0mm

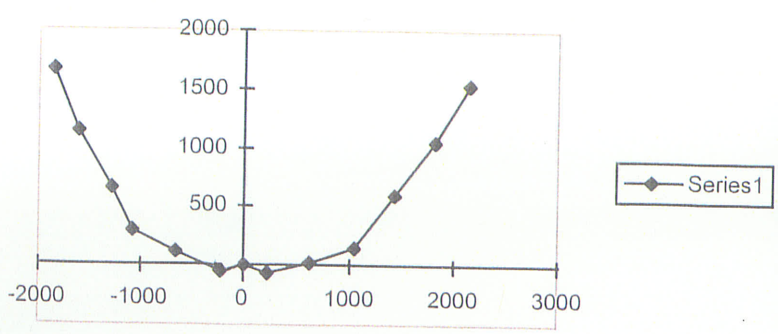
Post-treatment



AGE = 14 years
II = 1mm
Intercanine = 27.3mm e=0.71
Intermolar = 45.3mm



Post-retention



AGE = 20 years
II = 2.3mm
Intercanine = 27.3mm e=0.75
Intermolar = 44.0mm

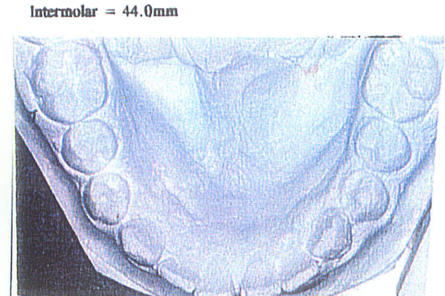
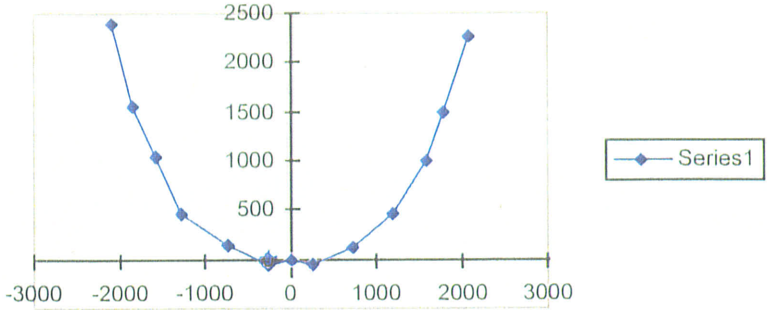
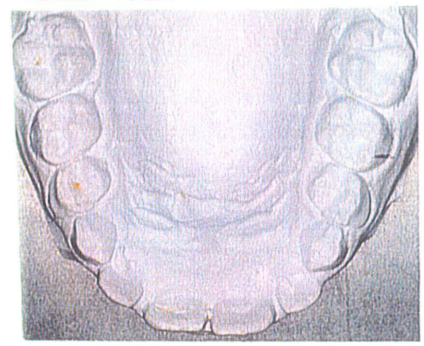


Figure 4.3A Changes in Maxillary Arch Form

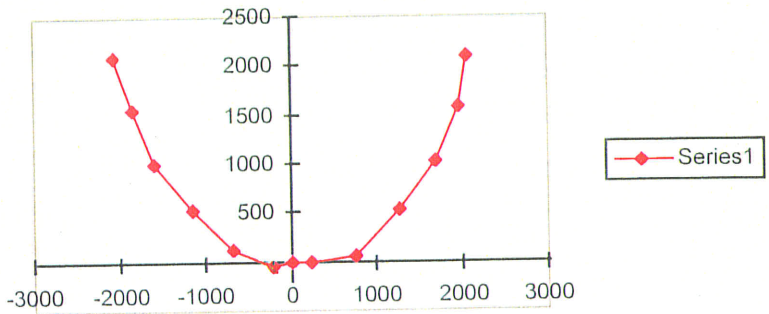
Pre-treatment



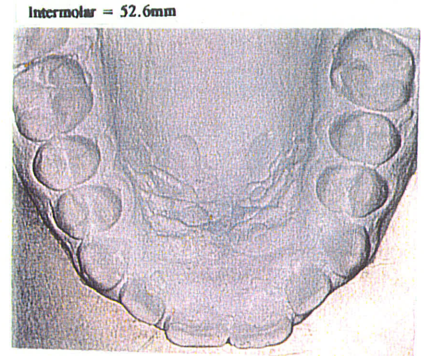
AGE = 9 years
II = 7.3mm
Intercanine = 32.0mm e=0.81
Intermolar = 50.6mm



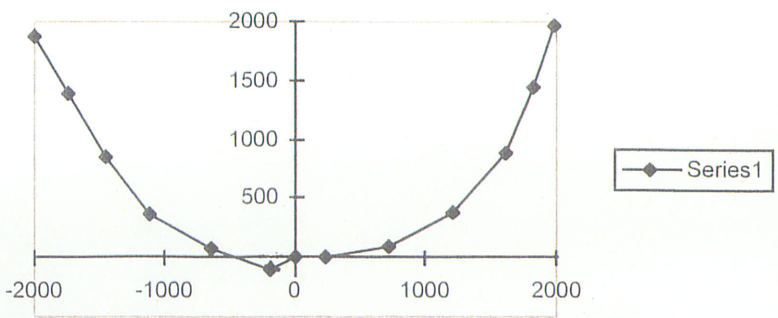
Post-treatment



AGE = 14 years
II = 6mm
Intercanine = 37.3mm e=0.65
Intermolar = 52.6mm



Post-retention



AGE = 21 years
II = 7.3mm
Intercanine = 35.0mm e=0.77
Intermolar = 52.0mm

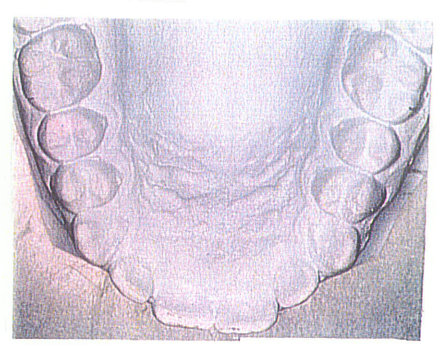
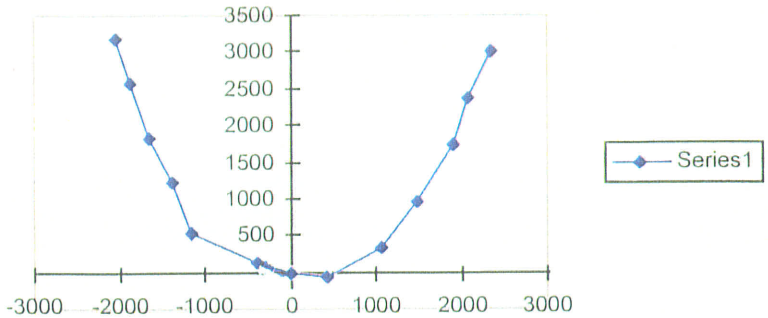
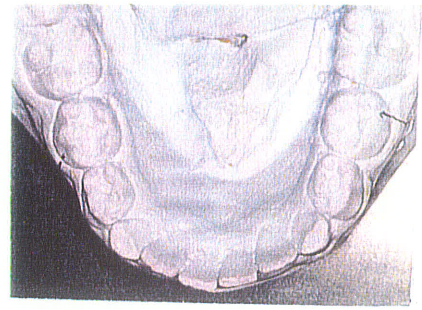


Figure 4.3B Changes in Mandibular Arch Form

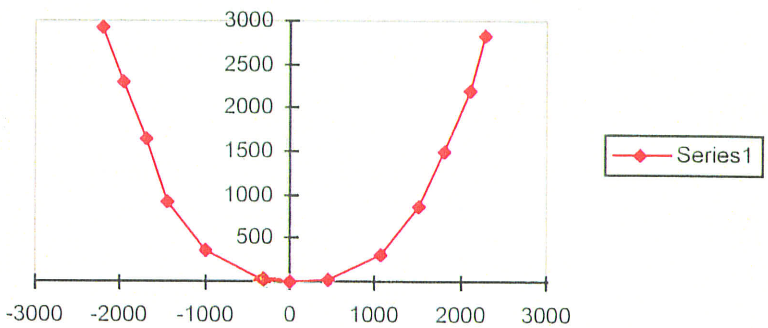
Pre-treatment



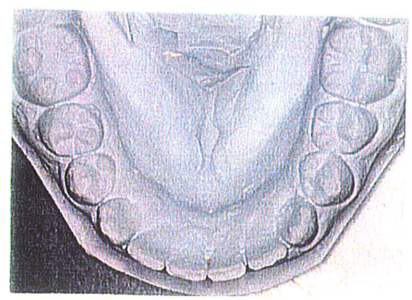
AGE = 9 years
II = 4mm
Intercanine = 27.3mm e=0.74
Intermolar = 42.6mm



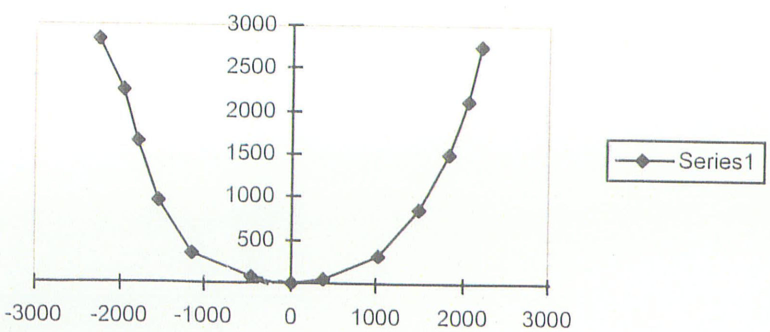
Post-treatment



AGE = 14 years
II = 3.3mm
Intercanine = 27.0mm e=0.71
Intermolar = 43.3mm



Post-retention



AGE = 21 years
II = 3.3mm
Intercanine = 27.3mm e=0.73
Intermolar = 45.3mm

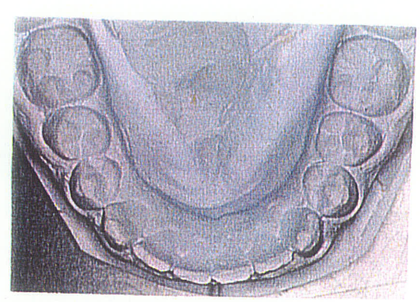
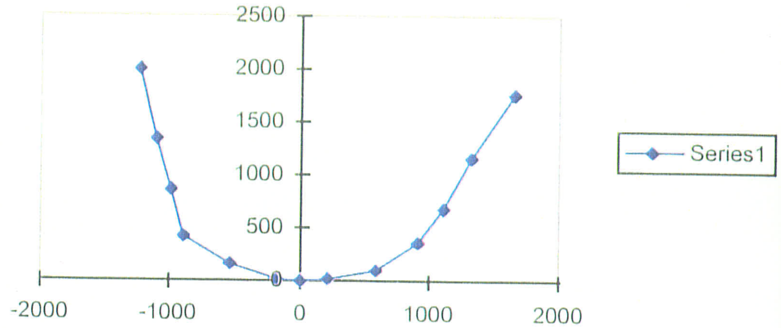
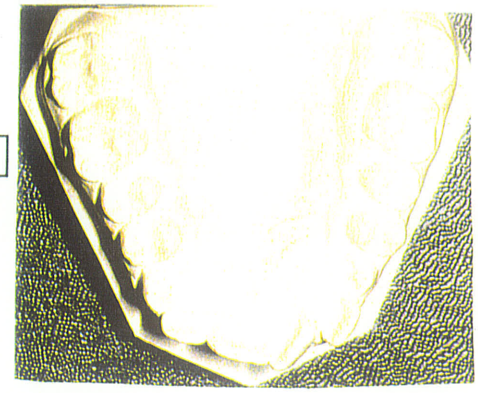


Figure 4.4A Changes in Maxillary Arch Form

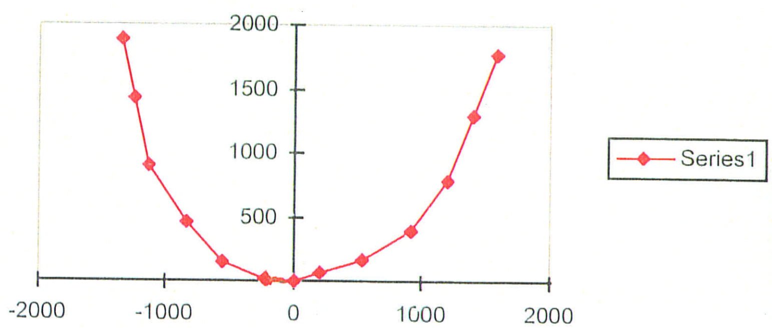
Pre-treatment



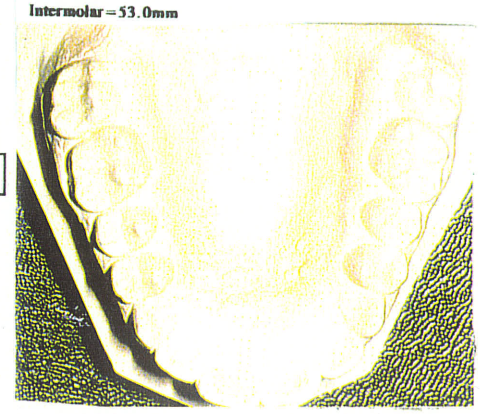
Age=12years 8months
II=4.3mm e=0.83
Intercanine=30.8mm
Intermolar 48.3mm



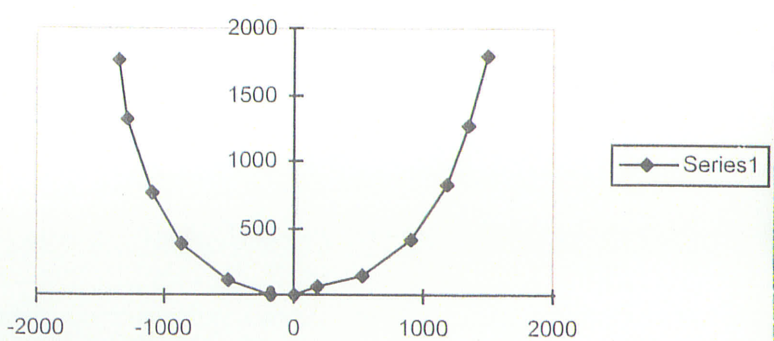
Post-treatment



Age=16years 2months
II=0mm e=0.67
Intercanine=30.8mm
Intermolar=53.0mm



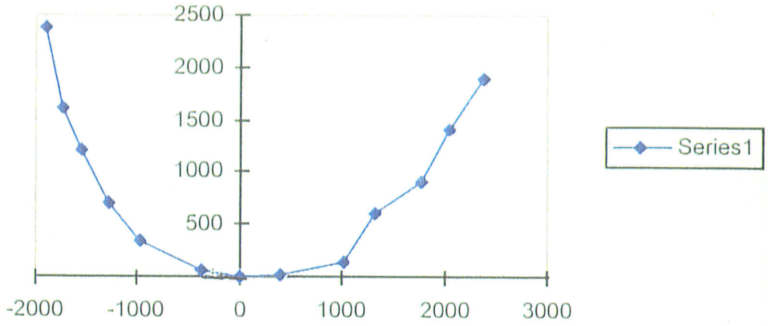
Post-retention



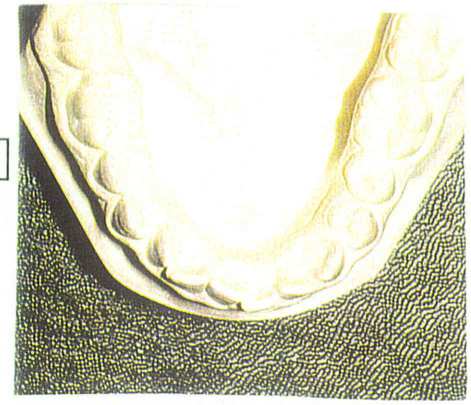
Age=21years 3months
II=2.3mm e=0.83
Intercanine=30.1mm
Intermolar=51.6mm

Figure 4.4B Changes in Mandibular Arch Form

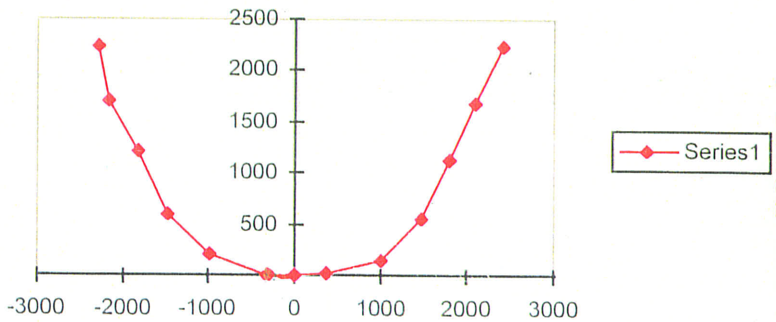
Pre-treatment



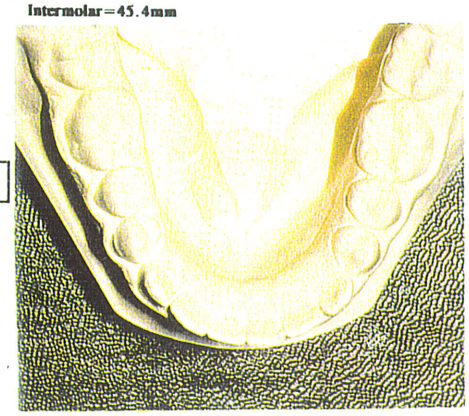
Age=12years 8months
II=2.0mm
Intercaine=23.5mm
Intermolar=42.7mm
e=0.79



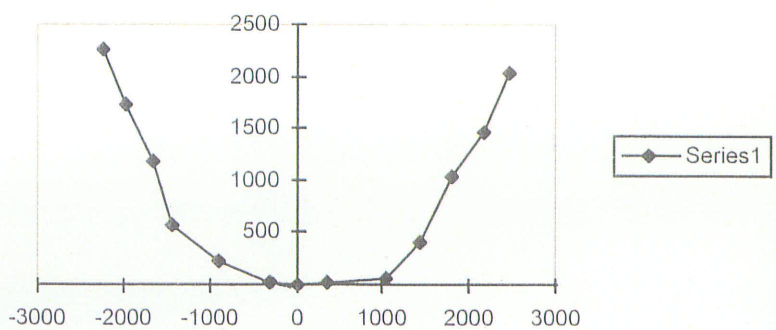
Post-treatment



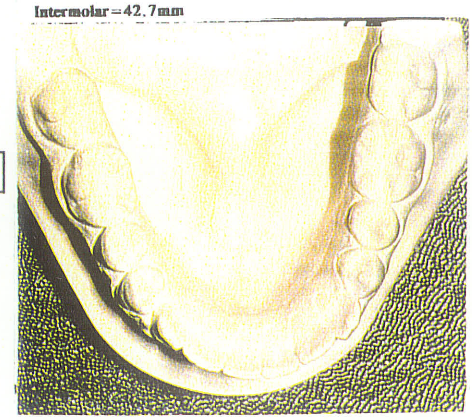
Age=16years 2months
II=0mm
Intercanine=23.5mm
Intermolar=45.4mm
e=0.60



Post-retention



Age=21years 3months
II=2.3mm
Intercanine=23.2mm
Intermolar=42.7mm
e=0.76



Summary of Results

The results of the study showed the following major features:

1. No statistically significant differences ($p < 0.05$) in the amount of relapse by arch (maxillary, mandibular) or gender (male, female), based on analysis of incisor alignments, or intercanine and intermolar widths, as illustrated by the F values in Table 4.1.1.

2. Maxillary intercanine widths increased through treatment as shown in Table 4.5.1 (mean = 2.1%) and decreased post-retention (mean=1.3%). Whereas, mandibular intercanine widths decreased through treatment as illustrated in Table 4.5.1 (mean = 2.4%) and decreased post-retention (mean = 1.3%, these changes were not significantly different ($p < 0.05$) from those noted in the untreated sample.

3. Intermolar widths also increased through treatment as shown in Table 4.6.1 (mean = 2.7%) and decreased in the post-retention period (mean = 1.3%). These changes did not significantly differ ($p < 0.05$) from those evident in the untreated population.

4. 89% of pretreatment arch forms were best described by an ellipse and 11% by parabolas. 87% of all post-retention arches were best described by ellipses and 13% by parabolas. Arch forms, therefore, appeared to become more rounded through treatment, but all returned to the more tapered form (pre-treatment) in the post-retention period.

DISCUSSION

5.1 Introduction

This study was undertaken to assess the changes brought about through three of the potential orthodontic treatment options available for the correction of a Class II division 1 malocclusion. These treatments were assessed via two methods (linear and arch form) with regard to the stability of the treatment as well as by contrasting tooth movements observed in the treated population with those of an untreated population with the same malocclusion. Furthermore, the methods of quantifying the amount and incidence of tooth movement were evaluated as a possible assay for orthodontic treatment quality.

Professional ethics require dental care providers to present patients with full and accurate information on the likely benefits, potential risks and costs of all possible treatment options. Unfortunately, accurate risk/benefit estimates for orthodontic treatment are often difficult to develop due to ongoing changes in the understanding of the processes of tooth movement within the arch (Little et al., 1981). These concerns are beginning to be addressed through legislation. For instance, in Ontario (Regulated Health Professional Act, 1991; 1993; 1994) the provincial licensing authorities for each health profession are required to "develop, establish and maintain programs and standards of practice of the profession".

This trend towards evidence-based care adds to the *apprentice-learned, experiential-consolidated* and expert-driven clinical decisions, made with careful reference to evidence mentioned in the literature. Such standards of care may then be used as benchmarks to judge the quality of care provided to individuals or groups of patients. Unfortunately, efforts to develop evidence-based standards (guidelines) for orthodontics lags well behind the initiatives developed for many aspects of medicine (Bader and Shugars, 1995). For instance, the standards for general dentistry in England are based on the literature but provide no indication of the level of evidence used in their development (Advisory Board in General Dental Practice, 1991). Similar criticisms may also be applied to guidelines developed by the American Dental Association (1995) and the College of Dental Surgeons of British Columbia (1993).

Yet, review of the literature underscores that such guidelines (standards) are crucial for all aspects of dentistry, including orthodontics. For instance, examination of treated cases has shown that, although improvement in the dentition can be achieved, there is a tendency to return to the original malocclusion in the post retention period (Lasher, 1934; Bishara et al., 1973; Bennet et al., 1975; Shaw et al., 1980; Richmond and Andrews, 1993).

In an attempt to devise uniform assessment criteria, the Peer Assessment Rating (PAR) index was developed to evaluate orthodontic treatment outcome (Richmond, 1993). Yet when applied to Class II div. 1 cases, this index showed that post-treatment results were maintained only in 60% of cases one year post-retention and in 38% 10 years post-retention. Although late lower anterior crowding was the principal discrepancy (Otuyemi, 1995), the results underscored the urgent need for orthodontic care (standards). Other criticisms include that the measurements were confined only to the arrangement of teeth within the arch, i.e., the following important parameters were excluded from this study:

- degree of improvement/worsening associated with treatment (i.e., effects)
- results as related to cost factor (i.e., do the benefits correlate with the associated treatment costs?)

Moreover, important criteria in the assessment of orthodontic care include the following:

- can treatment changes in the occlusal relationships between the maxillary and mandibular arches be objectively measured (quantified)? i.e., can these changes discriminate differences in treatment quality from one provider versus another? Ideally, different orthodontists should be able to provide the same standard of care to patients with analogous deformities.
- orthodontic treatment of Class II div. 1 cases may lead to improved function. How can these improvements be objectively assessed?
- an orthodontist's opinion may include significant improvements in aesthetics as a result of treatment, whereas,different parameters are important from the patient's perspective. These remain elusive in the absence of data relative to the stability of orthodontic realignment in Class II div. 1 cases.
- can the iatrogenic consequences following treatment for Class II div. 1 cases be accurately predicted?

Although the importance of these criteria cannot be overstated, their analysis was outside the scope of the current project.

5.2 Current Practices

Orthodontists define quality by cephalometric measures and the stability of treatment. Patients' criteria include the shortness of treatment time and the size of the bill (Moyers, 1989). The aim of the present study was to evaluate one of these criteria, namely stability, relative to three treatment options for the correction of Class II div. 1 malocclusions in growing patients (other important parameters must be resolved by future studies).

These issues and their implications are discussed in the following categories:

- incisor alignment
- intertooth widths
- arch form

5.3 Incisor Alignment

The most widely reported stability studies in the orthodontic literature are derived from the University of Washington (Little et al., 1981; Shields et al., 1985; Little et al., 1980, 1988; McReynolds et al., 1991; Riedel et al., 1992; Artun et al., 1996).

These data indicate that:

- incisor irregularity and crowding increase with cessation of retainer wear and without treatment;
- serial extraction in either arch has no bearing on the prevalence of future incisor irregularity;
- in some cases, the prevalence of post-treatment mandibular incisor crowding may be predisposed by fixed orthodontic therapy; and
- as the prevalence and extent of post-retention incisor crowding is both unpredictable and variable, patients should be appraised in writing of this potential outcome.

This study addressed several of the deficiencies of other studies that examined treatment effects and the stability of treatment. This study compared the changes evaluated in one malocclusion subgroup, rather than the examination of several malocclusions and pooling their cumulated changes (Shapiro, 1974; Gardner et al., 1976; Glenn et al., 1987). This study isolated the treatment modalities utilized in the correction of the malocclusion and compared them independently with the changes seen in an untreated population with the same malocclusion (Johnson, 1977; Sadowsky and Sakols, 1982). The mathematical modeling programme used allowed for the expression of individual arch form at each time period instead of comparing to one arch form (Scott, 1957; Pepe, 1975) or using a limited number of mathematical expressions to define arch shape (Raberin et al., 1993).

The results of the present study, however, indicated the following:

- the average irregularity index at T2 was x_{max} = 2.84 mm and x_{mand} = 2.06 mm in the treated group whereas that for the control untreated group x_{max} = 3.64 mm and x_{mand} = 2.90 mm;
- the average irregularity index at T3 was x_{max} = 3.81 mm and x_{mand} = 2.95 mm in the treated group, relative to x_{max} = 4.59 mm and x_{mand} = 3.72 mmin the control group

Then, based on Little's Irregularity Index:

Table 5.3.1 Little's Incisor Irregularity Index

INCISOR CROWDING (mm)	INDICATION
0 - 3.5 mm	clinically acceptable
3.5 mm - 6.5 mm	moderate crowding
> 6.5 mm	severe crowding

The current study's post treatment (T2) results may be interpreted as follows:

- 61% of the treated groups had clinically acceptable maxillary incisor alignment as compared with 49% of the control group;
- 78% of the treated groups had clinically acceptable mandibular incisor alignment as compared with 69% of the control group.

Similarly, the post-retention (T3) results showed:

- 58% of the treated group had clinically acceptable maxillary incisor alignment as compared with 39% of the control group;
- 65% of the treated group had clinically acceptable mandibular incisor alignment as compared with 54% of the control group.

These results may therefore be interpreted to indicate that changes in the treated groups of Class II div. 1 malocclusions are not inconsistent with those in the untreated control group with the same malocclusion, i.e., incisor malalignment is characteristic of this malocclusion category.

Few studies have been able to document long-term incisor stability following orthodontic treatment (Sandusky, 1983; Glenn, 1987; Rossouw et al., 1993). For instance, most studies have dealt with extraction treatment modalities indicate disappointing results (Little et al., 1981; Shields et al., 1985; Little et al., 1988; McReynolds et al., 1991). This is illustrated by Little et al. (1981) who reported an average incisor irregularity of 4.6 mm in 65 first-premolar extraction cases a minimum of ten years post-retention. The few studies that centered on incisor irregularity in a population treated with non-extraction modalities have also reported variable responses. For instance, Franklin (1996) reported remarkable stability of incisor alignment post treatment, i.e., 79% of a non-extraction treated group had clinically acceptable alignment at a minimum of 10 years post-retention (T3).

5.4 Intertooth Widths

The results from the present study confirmed the findings from previous studies, which showed that in non-extraction cases, intertooth widths are typically expanded, through treatment, although this was not maintained post-retention

(Barrow et al., 1952; Peak, 1956; Glenn, 1987; Little et al., 1988; Eslambolchi, 1994). In the present sample, all intercanine widths increased during treatment (x_{max} = 0.9 mm and x_{mand} = 0.3 mm) but all values decreased (x_{max} = -0.4 mm and x_{mand} = -0.5 mm) post-retention. Moreover, the values showed a statitically significant difference ($p < 0.05$) from those changes observed in the untreated control group from pretreatment to post-treatment (x_{max} = -0.3 mm and x_{mand} = 1.15 mm) and from post-treatment to post-retention (x_{max} = -0.6 mm and x_{mand} = -0.6 mm). Changes in the intercanine widths from post-treatment to post-retention (T2 - T3) in the treated groups were greater than those expected in the untreated control group. They were therefore not merely due to maturational changes derived from treatment.

Intermolar width demonstrated the most stable parameter and all widths increased in the treated groups (x_{max} = 1.18 mm and x_{mand} = 0.54 mm) whereas these values decreased (x_{max} = -0.43 mm and x_{mand} = -0.13 mm) post-retention. As none of the values differed significantly from those in the untreated control group, these findings were consistent with those of previously quoted studies of untreated populations (Moorrees, 1959; Lundstrom, 1968; Sinclair et al., 1983, Eslambolchi, 1994). They therefore indicated that the slight increase in intermolar width through treatment is crucial to the relative stability in the post-retention phase.

Evidence from the present study indicated that relapse in intertooth widths were opposite to the changes induced by treatment i.e., most values returned to approximately their pretreatment values. Clinically this implies that treatment objectives should always be based on original intertooth width values (Amott, 1962; Arnold, 1963; Shapiro, 1974; Little et al., 1990; Sadowsky, 1994; Bishara et al., 1996).

5.5 Arch Form

Based on treatment observations, Riedel (1960) derived a number of theorems related to the retention of orthodontic tooth movements in which theorem #9 states that "arch form" cannot be altered permanently by appliance therapy. Many studies have tried to define a universal/ideal arch form (Hawley, 1905), determine the shapes(s) of existing arch forms, establish a normal/ideal (see Table 2.3: Felton et al., 1988; Ferrario et al., 1994; Battagel et al., 1994) base results on an untreated population (see Table 2.5: Cohen, 1940; Scott, 1957; Pepe, 1975; Raberin, 1993), or quote results from limited case samples (< 20 patients) (see Table 2.4: Hellman, 1940; Johnson, 1977; Pepe, 1975).

In the present study, arch forms were evaluated from a series of points that closely represented the facial surface of the teeth to which orthodontic attachments were fixed. Eccentricity of the arch forms generated were then interpreted from the derived mathematical shape (parabola, ellipse, hyperbola). These definitions were, however, inherently limited by the posterior extension as the mesial of the first molar, i.e., the second and third molars were not erupted at the time of pretreatment assessment (average age = 10 years 3 months). Although this approach has been criticized (Neilans, 1968; Currier, 1969), this is not relevant in this study since:

- second molars are not always banded in orthodontic treatment (Hechter 1978) which could affect interfirst molar width;

- inclusion of the second molars (usually present at T2 and T3) in the arch form analysis would include a variable not present at T1, which might have impacted on the derived arch form (Sampson, 1981).

This study showed that pretreatment maxillary and mandibular arch form most closely resembled an ellipse. Whereas treatment broadened all arch forms, the overall geometric shape was not altered in that all post-treatment arch forms were also best described by an ellipse. This study also showed that arch form was altered by all treatment modalities (e = -0.07) although these changes were not held post-retention (e = 0.04), i.e. arch forms tended to relapse to their original form (retention devices are essential to the stability of orthodontic treatment).

5.6 Clinical Implications

The findings from this study have important implications for the development of treatment guidelines to assess orthodontic treatment:

- ideal occlusion is not necessarily a stable end point of orthodontic treatment. i.e., retention is equally important to orthodontic treatment as the active treatment phase;
- no one variable may facilitate the prediction of consequences following orthodontic treatment, although treatment objectives based on original intertooth widths and contouring all arch wires as closely as possible to the original arch shape may improve stability. Moreover, no option predisposes greater stability in subsequent arch form than others;
- the changes seen in an orthodontically treated group did not differ statistically from those seen in an untreated group with the same malocclusion. This suggests that arch form, defined by tooth location, has an inherent characteristic that should not be violated without the post-treatment application of retainers.

5.7 Assays of Orthodontic Quality

Standards of care are established in order to meet certain criteria when considering the type and provision of care. It is both possible and likely that standards considered realistic cannot be achieved in every dental practice. Quality assurance depends on the knowledge and ability as well as the awareness of the problems and responsibilities of all persons involved. But decisions, even if made on the basis of secure scientific and practical findings do exert great influence in their acceptance and application (Kimmel, 1992).

In orthodontics, quality of the treatment provided has been based on the:

- occlusion - post-treatment
  - post-retention

But both of these assessments are poorly defined and highly subjective. In an attempt to assay objectively the quality of orthodontic care provided, orthodontists have either tried to tighten up the criteria for previous methods of evaluation (Riedel, 1960) or devised new methods e.g. analysis of arch form, to assess the care provided (Currier, 1969).

In this investigation a strict and accurate method of data collection and interpretation was utilized to assess the effects of three orthodontic treatment modalities on tooth position in the transverse dimension. It was found that there was no difference among the three treatment options as well as no difference from those in an untreated population with the same malocclusion. From these results it can be postulated that in effect there is no difference in the stability of tooth position caused by the treatments investigated or that the analysis of tooth position (stability) is not an accurate method of analysis of the quality of treatment provided.

It is therefore suggested that other factors be looked at as assays of quality. These include:

- patient's assessment of the treatment provided
- function
- decrease /change in symptoms

However, methods for their assay have yet to be developed.

CONCLUSIONS

CONCLUSIONS

In common with other forms of care, orthodontics is subject to scrutiny and criticism (Vig et al., 1990). Reliable information on the benefits, costs and risks associated with treatment are not available. Due to this lack of objective data, conflicting assertions concerning orthodontic care standards are often expressed. Yet quantitative evidence for both effects and efficacy of treatments remains largely obscure.

In this study the effects, outcomes and stability of three treatment options were evaluated from the dental casts of 50 patients with Class II div. 1 malocclusion. The results showed the following major features:

- intercanine width generally decreased (6.5%) from post-treatment to post-retention, even when minimal expansion was a component of treatment. Also, the greater the increase in this dimension, the greater the decrease after treatment. As such, changes were not reflective of normal maturational changes in the dentition and may have resulted from the over expansion of this parameter to accomplish treatment objectives.

- intermolar widths appeared to remain relatively stable from post-treatment to post-retention.

- incisor irregularity and crowding generally increased. These changes appear to reflect the normal maturational changes in the dentition rather than the "relapse" associated with orthodontic treatment since they did not differ significantly for those of the untreated groups.

LIMITATIONS OF THE STUDY

LIMITATIONS OF THE STUDY

1. The need for adequate and complete records limited the examination of changes in the post-retention period.

2. The modeling programme to determine arch form assumed symmetry. The description of arch changes would have been more accurately quantified if a programme could be designed to analyze each half of the arch independently.

RECOMMENDATIONS FOR FURTHER RESEARCH

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Based on the results of this investigation, recommendations for future studies in the area of retention and stability include:

1. prevalence of relapse in other Class II division 1 malocclusion subgroups;

2. prevalence of relapse in non-growing patients;

3. prevalence of relapse in other treatment modalities for the correction of Class II division 1 malocclusions;

4. the assessment of patients' expectations and perceptions of relapse;

5. other methods to assay the quality of orthodontic care provided.

REFERENCES

Amott RD. A serial study of dental arch measurements on orthodontic subjects. MS.. Thesis, Northwestern University, Chicago, Ill. 1962.

Angle EH. Treatment of Malocclusion of the Teeth, 7th ed., Philadelphia, 1907, SS White Dental Mfg. Co.

Arnett GW. Facial keys to orthodontic diagnosis and treatment planning. Part 1. Am J Orthod and Dentofac Orthop 1993;103:299-312.

Arnold ML. A study of the changes of the mandibular intercanine and intermolar widths during orthodontic treatment and following a post retention period of five or more years. M.S.D. Thesis, University of Washington, Seattle, 1963.

Artun J. Long-term stability of mandibular incisors following successful treatment of Class II div. 1 malocclusions. Angle Orthod 1996;66:229-38.

Ashton CM, Johnson ML, et al. A method of developing and weighting explicit process of care criteria for quality assessment. Ed Care 1994;32:755-70.

Bader JD and Shugars DA. Variation, treatment outcomes, and practice guidelines in dental practice. J Dent Educ. 1995; 59:61-95.

Barrow A and White J. Developmental changes of the maxillary and mandibular dental arches. Angle Orthod. 1952; 22:41-6.

Basset LW et al. Quality determinations of mammography. Clinical practice guideline. No. 13. Rockville, Md.: Department of Health and Human Services, 1994. (AHCPR publication s no 95-0632).

Battagel JM. Individualized catenary curves: their relationship to arch from and perimeter. Brit J Orthod. 1996; 23:21-8.

BeGole EA. Application of the cubic spline function in the description of dental arch form. J Dent Res 1980; 59: 1549-56.

Bennet R. The Bennet Angle. Dtsch Zahnarztl Z. 1975;35:315-7.

Berg R. Evaluation of orthodontic results - a discussion of some methodological aspects. Angle Orthod. 1991;61(4):261-6.

Bernstein SJ et al. Coronary angiography: a literature review and ratings of appropriateness and necessity. Santa Monica, Calif.:RAND, 1992. (Publication JRA-03-CWF/HF).

Berwick DM. Continuous improvement as an ideal in health care. N Engl. J Med 1989;320;53-6.

Biggerstaff RH. Three variations in dental arch form estimated by a quadratic equation. J Dent Res 1972; 51: 1509.

Bishara SE et al. Stability of intercanine width, overbite. and overjet correction. Am J Orthod and Dentofac Orthop. 1973;63:588-75.

Bishara SE et al. Comparisons of the dental arch changes in patients with Class II division 1 malocclusions: extraction versus nonextraction treatments. Angle Orthod. 1994;64(5):351-8.

Bishara SE et al. Longitudinal comparisons of dental arch changes in normal and untreated Class II, division 1 subjects and their clinical implications. Am J Orthod and Dentofac Orthop. 1996; 110(5): 283-90.

Black GV. Descriptive Anatomy of the Human Teeth, 5th ed., Philadelphia, 1902, SS White Dental Mfg. Co.

Blum H. Biological shape and visual science. J Theor. Biol. 1973;38:205-87.

Blum H, Webber RL. Angular variants in developing human mandibles. Science;1979:206:689-91.

Blumenthal D. Effects of market reforms on doctors and their patients. Health Aff (Millwood) 1996;15:170-84.

Bonwill WGA. Geometrical and mechanical laws of articulation. Tr Odont Soc Penn 1884-1885;6:119-133.

Bookstein FL. The measurement of biological shape and shape change. Lecture notes in biomathematics. vol. 24. New York;1978; Springer-Verlag.

Bookstein FL. Fitting conic sections to scattered data. Comp. Graph. Image Proc. 1979;9:56-71.

Brader AC. Dental arch form related to intraoral forces. Am J Orthod 1972; 61:541-561.

Broomell IN. Anatomy and Histology of the Mouth and Teeth. 2nd ed., Philadelphia 1902; P Blakiston's Son & Co, 99.

Brook RH, Appel FA. Quality of care assessment: choosing a method for peer review. N Engl. J Med 1973;288:1323-9.

Brook RH et al. Assessing the ability of medical care using outcome measures: an overview of the method. Med Care. 1977;15:Suppl.

Brook RH et al. Overview of adult health measures fielded in RAND's Health Insurance Study. Med Care 1979;17:Suppl.

Chate RA. The burden of proof: a critical review of orthodontic claims made by some general practitioners. Am J Orthod Dentofac Orthop 1994;106:22A.

Cohen JT. Growth and development of the dental arches in children. Am Dent Assoc 1940;27;1250-60.

Currier JH. A computerized geometric analysis of human dental arch form. Am J Orthod 1969; 56:165-175.

De La Cruz A et al. Long-term changes in arch form after orthodontic treatment and retention. Am J Orthod Dentofac Orthop 1995;107:518-530.

Donabedian A. Explorations in quality assessment and monitoring. Vol. 1. The definition of quality and approaches to its assessment. Ann Arbor, Administration Press, 1980.

Donabedian A. Explorations in quality assessment and monitoring. Vol. 2. The definition of quality and approaches to its assessment. Ann Arbor, Mich.:Health Administration Press, 1982.

Donabedian A. Explorations in quality assessment and monitoring. Vol. 3. The definition of quality and approaches to its assessment. Ann Arbor, Mich.:Health Administration Press, 1985.

Eccles M et al. North of England Evidence Based Guidelines Development Project: Methods of guideline development. BMJ 1996;312:760-2.

Epstein AM. Definitions, history, scope and characteristics of physician report cards. In: Physician assessment in the 21st century: ABIM's role. Philadelphia: American Board of Internal Medicine. 1995:35.

Eslambolchi S. A serial study of mandibular incisor alignment from age 20 to 70 years. Diploma Thesis, University of Toronto, 1994.

Felton MJ et al. A computerized analysis of the shape and stability of mandibular arch form. Am J Orthod Dentofac Orthop 1988; 92:478-483.

Ferrario VF et al. Mathematical definition of the shape of dental arches in human permanent healthy dentition. EJO 1994;16:287-94.

Franklin WS. A longitudinal study of dental and skeletal parameters associated with the stability of orthodontic treatment. MS Thesis, University of Toronto, 1996.

Friel S. The diagnosis of malocclusion of the teeth. Dent Cosmos 1914;56:825-832.

Gardner SD, Chaconas SJ. Post-treatment and post-retention changes following orthodontic therapy. Angle Orthod 1976;46(2):151-61.

Gauzer B. When doctors are the problem. Parade. April 14, 1996:4-6.

Gilpatric WH. Arch predetermination - is it practical? J Am Dent Assoc 1923;10:553-573.

Glenn G et al. Nonextraction orthodontic therapy: Post treatment dental and skeletal stability. Am J Orthod Dentofac Orthop 1987;92:321-8.

Gold MR et al. A national survey of the arrangements managed care plans make with physicians. N Engl J Med 1995;333:1678-83.

Graber TM, Vanarsdall RL. Orthodontics: Current Principles and Techniques. St. Louis. Mosby 1986.

Graber TM, Vanarsdall RL. Orthodontics: Current Principles and Techniques. St. Louis. Mosby 1994.

Gray BH. The profit motive and patient care. Cambridge, Mass: Harvard University Press, 1991.

Gruneberg J. The symmetroscope: Dent Cosmos 1912;54:490-491.

Hawley CA. Determination of the normal arch and its application to orthodontics. Dental Cosmos. 1905;47:541-57.

Hechter FJ. Symmetry and dental arch form of orthodontically treated patients. J Can Dent Assoc. 1978;44:173-84.

Hellman M. Dimension vs. form in teeth and their bearing on the morphology of the dental arch. Int J Orthod 1919;5:615-651.

Hellman M. Orthodontic results many years after treatment. Am J Ortho Oral Surg 1940;26:843-853.

Hrdlicka A. The normal dental arch. Dent Cosmos 1916;58:1029-1032.

Hunter J. The natural history of the human teeth. Am Lib Dent Sci 1939;1:1-75.

Izard G. New methods for the determination of the normal arch by function of the face. Int J Orthod. 1927;13:582-95.

Johnson KC. Cases six years postretention. Angle Orthod 1977;47:210-220.

Jones ML and Richmond S. An assessment of the fit of a parabolic curve to pre- and post-treatment dental arches. Brit J Orthod 1989;16:85-93.

Joondeph D. et al. Pont's Index: a clinical evaluation. Angle Orthod 1970;40:112-118.

Kato S et al. Study on the positions of teeth and the average form of dental arches. J Nihon Univ School Dent 1964; 6:111-121.

Kimmel K. Realistic standards for quality assurance. Int Dent J1992;42:427-432.

Lasher MC. A consideration of the principles of mechanical arches as applied to the dental arch. Angle Orthod 1934;4:111-121.

Lavelle CLB. The shape of the dental arch. Am J Orthod 1975;67:176-79.

Leape LL. Error in medicine. JAMA 1994;272:1851-7.

Legan HL. Clinical considerations in the use of protraction headgear. J Clin Orthod 1992;26:87-91.

Little RM. The incisor irregularity index: A quantitative score of mandibular anterior alignment. Am J Orthod. 1975;68:554-563.

Little RM. Stability and relapse of dental arch alignment. Brit J Orthod 1980;17:235-241.

Little RM et al. Stability and relapse of mandibular anterior alignment - first premolar extraction cases treated by edgewise orthodontics. Am J Orthod 1981;80:349-363.

Little RM et al An evaluation of changes in mandibular anterior alignment from 10 to 20 years post-retention. Am J Orthod Dentofac Orthop. 1988;93(5):423-428.

Little RM et al. Serial extraction of first premolars - post-retention evaluation of stability and relapse. Angle Orthod. 1990;60(4):255-262.

Lohr KN et al. Use of medical care in the RAND Health Insurance Experiment: diagnosis- and service-specific analyses in a randomized controlled trial. Med. Care 1986;24:Supple:S1-S87.

Lohr KN et al. Medicare: a strategy for quality assurance. V. Quality of care in a changing health care environment. Qual. Rev Bull 1992;18:120-6.

Lu KH. Analysis of dental arch symmetry. J Dent Res 1964;43:780.

Lu KH. An orthogonal analysis of the form, symmetry and asymmetry of the dental arch. Arch Oral Biol 1967;11:1057-1069.

Lohr KN et al. Medicare: a strategy for quality assurance. V. Quality of care in a changing health care environment. Qual. Rev Bull 1992;18:120-6.

Lundstrom A. changes in crowding and spacing of the teeth with age. Dent Proactit. 1969; 19(6):218-224.

MacConaill MA and Scher EA. The ideal form of the dental arcade, with some prosthetic application. Dent Rec 1949;69: 285-302.

McCoy DJ. A consideration of normal arch form and some of the methods for determining it. Int J Orthod 1919;5: 697-723.

McGlynn EA et al. Hysterectomy: a literature review and ratings of appropriateness. Santa Monica, Calif.: RAND, 1992 (Publication JR-04).

McReynolds DC and Little RM. Mandibular second premolar extraction - post-retention evaluation of stability and relapse. Angle Orthod. 1991;61(2):133-144.

Mills LF and Hamilton PM. Epidemiological studies of malalignment - a method for computing dental arch circumference. Angle Orthod 1965; 35:244-248.

Moorrees CFA and van der Linden FPGM. editors. Orthodontics: evaluation and future. The Netherlands: Samson Staflen, Alphen aans den Rijn, 1988.

Moyers RE. Quality assurances in orthodontics. Am J Orthod Dentofac Journal Orthop 1989;97(1):3-9.

Mulley AG, Jr. Industrial quality management science and outcomes research: responses to unwanted variation in health outcomes and decisions. In: Blumenthal D, Scheck AS, eds. Improving clinical practice: total quality management and the physician. San Francisco: Jossey-Bass, 1995:73-107.

Neilans LC. A computerized analysis of human dental arch form as compared to the catenary curve. M.S.. Thesis, Temple University: 1968.

North of England Asthma Guideline Development Group. North of England evidence Based Guidelines Development Project: summary version of evidence based guideline fro the primary care management of asthma in adults. BMJ 1996;312:762-6.

North of England Stable Angina Guideline Development Group. North of England Evidence Based Guidelines Development Project: summary version of evidence based guideline for the primary care management of stable angina. BMJ 1996;312:827-32.

Otuyemi OD. Methods of grading and assessing malocclusion: a review. Aust Orthod J 1995;14:21-7.

Paquette DE et al. A longterm comparison of nonextraction and premolar extraction edgewise therapy in "borderline" Class II patients. Am J Orthod and Dentofac Orthop 1992;102:1-14.

Peak JD. Cuspid stability. Am J Orthod 1956;42:608-14.

Pepe SH. Polynomial and catenary curve fits to human dental arches. J Dent Res 1975; 54:1124-1132.

Popovich F. A review of studies from the Burlington Growth Centre, 1956-1989. In: Essays in Honour of Robert E. Moyers. W.S. Hunter and D.S. Carlson (Eds.), Craniofacial Growth Series 24. Centre for Human Growth and Development, The University of Michigan, Ann Arbor, 1991:313-344.

Proffit WR. Contemporary Orthodontics Mosby 1986.

Raberin M et al. Dimensions and form of dental arches in subjects with normal occlusions. Am J Orthod Dentofac Orthop. 1993;104:67-72.

Richmond D and Andrews M. Orthodontic treatment standards in Norway. Eur J Orthod. 1993;15:7-15.

Riedel RA. A review of the retention period. Angle Orthod. 1960;30(4):179-199.

Riedel RA et al. Mandibular incisor extraction - post-retention evaluation of stability and relapse. Angle Orthod 1992;62:103-16.

Robinson JC, Casalino LP. Vertical integration and organizational networks in health care. Health Aff (Millwood) 1996;15(1):7-22.

Rossouw PE et al. A longitudinal evaluation of the anterior border of the dentition. Am J Orthod Dentofac Orthop. 1993;104:146-152.

Sadowsky C and Sakols EI. Long-term assessment of orthodontic relapse. Am J Orthod. 1982;82:456-463.

Sadowsky C et al. Longterm stability after orthodontic treatment: nonextraction with prolonged retention. Am J Orthod and Dentofac Orthop 1994; 106:243-249.

Sampson PD Dental arch shape: a statistical analysis using conic sections. Am J Orthod 1981; 79:535-547.

Wheeler RCA. A Text Book Dental Anatomy and Physiology. 2nd ed., Philadelphia, 1950; Saunders Co. 196-215:352-406.

Williams PN. Determining the shape of the normal arch. Dent Cosmos 1917;59: 695-708.

Wilson A, McDonald P. Comparison of patient questionnaire, medical record and audio tape in assessment of health promotion in general practice consultations. BMJ 1994; 309:483-5.