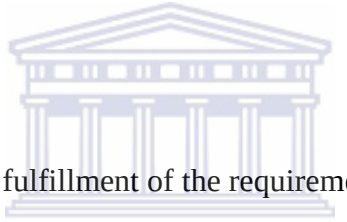
Changes in arch dimensions after extraction and non-extraction orthodontic treatment

EARL ARI MAC KRIEL



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Key words

1. Arch dimensions
2. orthodontic extractions
3. non-extraction
4. arch width
5. arch length
6. inter-canine width
7. inter-molar width
8. inter-premolar width

Abstract

Changes in arch dimensions after extraction and non-extraction orthodontic treatment

MSc Thesis, Department of Orthodontics, Faculty of Dentistry, University of the Western Cape

Extraction of teeth in orthodontics has always been a controversial topic. The literature is inconclusive about the changes in arch width and arch length during non-extraction and premolar extraction orthodontic treatment.

Aim: The aim of this study was to determine whether there are changes in the interdental arch widths and arch lengths of the mandibular and maxillary arches during non-extraction and extraction orthodontic treatment.

Materials and Methods: The records of 78 patients treated by one orthodontist were used for this study. Three treatment groups were selected: a nonextraction group (Group NE), a group treated with extraction of maxillary and mandibular first premolars (Group 44), and a group treated with extraction of maxillary first premolars and mandibular second premolars (Group 45).

The arch width measurements were measured in the inter-canine, inter-premolar and inter-molar areas. The arch length was measured as the sum of the left and right distances from mesial anatomic contact points of the first permanent molars to the contact point of the central incisors or to the midpoint between the central incisor contacts, if spaced.

Data analysis: Statistical analysis included descriptive statistics of the data, analysis of the correlation matrices, Wilcoxon Signed Rank tests and Kruskal-Wallis tests of the changes which occurred during treatment.

Results: The intercanine widths in the mandible and maxilla increased during treatment in all three groups, with the extraction groups showing a greater increase than Group NE ($p<0.05$). An increase in the inter-premolar arch widths in both dentitions occurred in Group NE ($p<0.05$). Group 45 showed an increase in mandibular inter-first premolar arch width ($p<0.05$) and Group 44 showed a decrease in mandibular inter-second premolar arch width ($p<0.05$). Both extraction groups had a decrease in the inter-second premolar arch width in the maxilla, with a statistically significant decrease in Group 44 ($p<0.05$). There was a slight increase in intermolar arch width in both dentitions in Group NE ($p>0.05$), while the extraction groups showed a decrease in these inter-molar widths ($p<0.05$). There were no statistically significant differences between the inter-canine and inter-molar arch width changes between the two extraction groups ($p>0.05$). In Group NE the mandibular arch length increased ($p<0.05$), while the maxillary arch length remained essentially unchanged. Both extraction groups showed decreases in arch length in the dentitions ($p<0.05$), with greater decreases occurring in the maxilla. The difference in arch length change between the two extraction groups was not significant ($p>0.10$).

Conclusion: The inter-canine arch width increased in all three treatment groups, more so in the two extraction groups. From this it is evident that extraction treatment does not necessarily lead to narrowing of the dental arches in the canine region. The inter-second premolar arch width decreased in both extraction groups. Non-extraction treatment resulted in an increase in the inter-premolar and inter-molar arch widths. Inter-molar arch width decreased in both extraction groups. The arch lengths of both extraction groups decreased during treatment, more so in group 45. Greater arch length decreases occurred in the maxilla than the mandible in all the treatment groups.

June 2008

DECLARATION

I hereby declare that *Changes in arch dimensions after extraction and non-extraction orthodontic treatment* is my own work, that it has not been submitted before for any degree or examination at any university, and that all the sources I used or quoted have been indicated and acknowledged by complete references.

Earl A. Mac Kriel June 2008

Signed: _____

_____day of_____2008

The work reported in this thesis was carried out in the Department of Orthodontics, Faculty of Dentistry, University of the Western Cape, Tygerberg, South Africa.

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Chapter 1

Introduction

Extraction versus non-extraction orthodontic treatment will probably always be a topic of discussion in orthodontics. Angle (1907) had a firm belief against the extraction of teeth. Sometimes extractions are necessary, but often orthodontists will differ in their opinion of whether it is necessary to extract teeth or treat the malocclusion without the extraction of teeth (Case 1964).

In orthodontics, extraction of teeth is one of the options in the treatment of malocclusions. The most commonly extracted teeth for orthodontic treatment are premolars (Weintraub et al 1989).

Although a lot of research has been done on the arch width and arch length changes during non-extraction and premolar extraction orthodontic treatment, the literature is not conclusive. Most of the authors identified in the literature studied either first premolar extraction samples or their extraction samples included cases having a combination of various extraction sequences.

Some literature has suggested that extraction of premolars will lead to narrowing of the inter-molar area (Gardner and Chaconas 1976, Shearn and Woods 2000, McReynolds and Little 1991). These authors suggest that when the second premolars are extracted and the molars are moved into a narrower area more anterior in the mouth, the arch widths decrease. The narrower dental arch may contribute to the appearance of “black triangles” in the corners of the mouth (Dierkes 1987). Gianelly (2003), however, found the increase in the inter-canine width in his extraction sample to be larger than in the non-extraction cases. In the same study he found the inter-molar widths in both extraction and non-extraction cases essentially unchanged. Johnson and Smith (1995) studied the frontal photographs of patients treated with extraction of four first premolars and of patients

treated non-extraction, and found that the transverse arch width at any particular location in the buccal segment is maintained or slightly enlarged after extraction.

Some authors have reported that the arch length is reduced in both nonextraction and extraction cases (Shapiro 1974, Luppanapornlap and Johnson 1993). Paquette, Beattie and Johnston (1992) also found that the arch length decreased in extraction cases, but differed from others in that they found an increase in arch length in non-extraction cases.

The objective of this study was to study the changes in the dental arch width in the canine, premolar and molar areas of dental arches as well as the changes in the dental arch lengths before and after orthodontic treatment in three groups of patients. One group was treated non-extraction (Group NE), one extraction group was treated with extraction of four first premolars (Group 44) and the other extraction group was treated with extraction of maxillary first and mandibular second premolars (Group 45).

Two extraction samples were chosen to compare non-extraction treatment with extraction treatments, and also to evaluate changes in arch width and arch length when different premolar extraction sequences are used during orthodontic treatment. In this study the arch widths and arch lengths of both the mandible and maxilla were measured. Many other studies have measured only the mandibular arch width changes. Some of the studies measured only inter-canine and inter-molar arch width changes, but the inter-premolar arch width changes were not measured in many of the previous studies. Post retention changes were not studied.

The literature review in Chapter 2 considers papers evaluating extractions in orthodontics and the changes in arch width and arch length that occur with non-extraction and extraction orthodontic treatment. In Chapter 3 the research design and methodology are explained. In Chapter 4 the results regarding the pre- and post-treatment changes in the arch width and arch length are described. The Discussion follows in Chapter 5 where the results are compared with those of other studies in the literature. An overview of the findings of this study and conclusions are presented in Chapter 6.

Chapter 2

Literature review

2.1 Extractions in Orthodontics

As in other fields, orthodontics has issues that are surrounded by a lot of controversy. Orthodontists will differ from each other with regards to which treatment is most suitable for a certain case, and this is also probably true for any other specialist field. An important issue which is often debated in orthodontics is whether to extract teeth or to treat the malocclusion without extractions (Case 1964). In orthodontics extraction of teeth is only one of many treatment options which are available to the practitioner.

Angle was of the opinion that in the normal occlusion all 32 permanent teeth should occupy their normal positions (Angle 1907). According to him there is no place for extractions in orthodontics. Angle believed that a full complement of teeth would establish the best harmony, and nature would allow this to happen through growth, development and function. Lundstrom (1925) stated that the apical base also needed to be considered, as orthodontic treatment was not necessarily accompanied by the development of the apical base. He believed that the occlusion that will be attained by orthodontic treatment cannot be maintained if the apical base position is not in harmony with the position of the teeth. Case (1964) was of the opinion that in orthodontics extraction of teeth is necessary to relieve the crowding, as well as to aid the stability of the treatment. He believed that new bone could not be induced to grow beyond its inherent size.

Dewel (1964) states that before Angle's time extractions were far too common. According to Dewel (1964) both Angle and Case played an enormous part in the development of early orthodontics, although they had widely different opinions on the subject of extraction of teeth in orthodontics.

Tweed (1944), like Angle, believed that normal occlusion or perfect facial aesthetics can never be attained without the full complement of teeth. At the time Tweed firmly believed in non-extraction treatment, and practiced it for a number of years. However after recalling patients for evaluation, he came to the conclusion that he did not achieve what he had set out to do in many of these patients he treated non-extraction. He then reviewed his approach to treatment, and came to believe that when a discrepancy between tooth size and the capacity of basal bone does exist, it would be better to remove teeth to bring about a balance between the dentition and basal bone. Tweed re-treated these patients with the extraction of premolars and achieved satisfactory results. Gradually the pendulum swung in favor of including extractions, but the issue was not totally resolved.

Watson (1980) takes the question further and asks under what special circumstances we should resort to tooth removal as a contributing factor to improving the patient's total health? He states that the decision to extract teeth must be made on an individual basis and not by general classes of malocclusion.

Travess et al (2004) did a study on extractions and stated that several factors affect the decision on whether to extract teeth. The patient's medical history, the attitude to treatment, oral hygiene, caries rate and the quality of teeth are all influential factors, according to their study. Weintraub et al (1989) stated that on an individual basis a number of factors enter the extraction decision. The factors include aetiologic and morphologic features of the malocclusion, specific objectives of the treatment, and the technique selected to accommodate the desired result. Their study canvassed opinions among orthodontists in Michigan in the United States of America, who indicated that about half of the patients in their practices had teeth extracted as part of treatment; and of this group about 70% had four premolars extracted. A study by Peck and Peck (1979) on the frequency of extractions in a single orthodontic practice in the United States of America, reported the extraction rate to be 42.1%.

O'Connor (1993) did a survey among orthodontic specialists in the United States on the trends in orthodontic practice. The survey revealed that more than half of the responding

orthodontists had reduced their extraction rate during the previous 5 years. Of the 800 responding orthodontists only about 4% reported an increase in their rate of extraction cases.

Extraction of teeth in the permanent dentition has become one of the most common treatment strategies for correcting Class11 malocclusions (Heiser et al 2004). Extractions are also a common consideration in the orthodontic management of dental crowding. Orthodontists may consider extractions in cases of jaw growth discrepancy, such as Angle Class 11 relationships, tooth pathology or injury (Peck and Peck 1979). The extraction of the four first premolars can be considered in cases with severe dento-alveolar protrusion, as well as in cases with a significant arch length deficiency (Shields, Little and Chapko 1985).

Shearn and Woods (2000) state that according to earlier studies premolars are probably the most commonly extracted teeth for orthodontic purposes. They attribute this to the fact that premolars are conveniently located between the anterior and posterior segments.

Extraction patterns also differ, as seen in the literature; e.g. Gianelly (2003) and Bishara et al (1994) had samples having had extraction of four first premolars, Shearn and Woods (2000) had an extraction sample which comprised patients having had mandibular first and mandibular second premolar extractions, and others with a combination of different maxillary premolar extractions.

The criticism of some orthodontists is that extraction treatment results in a narrower dental arch when compared with nonextraction treatment outcomes (Ho and Kerr 1987). It is also believed that extracting the first four premolars results in a narrower dental arch and unaesthetic black triangles at the corners of the mouth is a result of the dentition being too small for the mouth when the lips are extended during smiling (Gianelly 2003). McNamara (2000) attributes these dark spaces to a maxillary deficiency, meaning a deficiency in the transverse or sagittal dimension or both.

Hagler, Lupini and Johnson (1998) compared extraction and non-extraction treatment results in African American patients. They found that extraction treatment tends to flatten the profile, whereas non-extraction treatments tend to make the profile more protrusive.

Baumrind et al (1996) evaluated the decision-making patterns of a representative group of orthodontic clinicians who were treating 100 adolescent and 48 adult subjects. In this study little association was observed between clinician agreement on Angle classification and clinician agreement on whether or not to extract.

If we knew where we end up with extraction and non-extraction treatment, we could rationalize the decision whether we want to extract or not to extract. Ultimately we want to treat the patient to achieve the most aesthetic and functional results.

A study of the literature makes it clear that in some cases extractions are necessary if treatment goals are to be achieved. The premolars are the teeth most commonly extracted for orthodontic purposes, although different extraction patterns of premolars may be involved. The long-term consequences of extraction of teeth can only be appreciated by time and study. The debate still continues over which treatment, extraction or non-extraction orthodontic treatment, gives better long-term results.

2.2 Arch width

2.2.1 Arch width changes during normal growth

During normal growth there will be an increase in arch width as the child grows. The dental arch undergoes changes from birth until mid-adulthood. The arch widths in the intercanine and intermolar areas are significantly increased between three and 13 years of age (Bishara et al 1997). This occurs in both the maxillary and mandibular arches. After the permanent dentition has erupted, there is a slight decrease in the dental arch width, more in the inter-canine area than the intermolar area (Bishara et al 1997). Bishara and

his co-workers also found that on average the mandibular inter-canine width is established at around 8 years of age (Bishara et al 1997).

Knott (1972) did a longitudinal study of dental arch widths at four stages of dental development and found that for most individuals, the maximum inter-canine diameter of both arches showed little change after the stage of permanent dentition was attained. In the mandibular arch it was found that the increase in the inter-canine width occurred largely before the eruption of the permanent canine teeth.

2.2.2 Growth in Males and Females

Knott (1972) established that the average size of the dental arch was greater for males than for females. This was found to be the same for both the deciduous and permanent dentitions. In their studies on growth changes in the arch width Knott's (1972) study was supported by DeKock (1972) who also found that inter-molar and inter-canine arch widths did not change after the age of 13 years in females and age 16 years in males. DeKock (1972) found that there was a small, but statistically significant increase in arch width from 12 to 15 years of age in males.

In a study of untreated individuals Barrow and White (1952) showed that the inter-canine width decreased by varying amounts after the mid-teen years. They also reported that a moderate increase in dental arch width can be expected, particularly in the anterior regions, until the permanent canines erupt.

Sinclair and Little (1983) found that the inter-canine width of untreated individuals with normal occlusion decreased into early adulthood.

2.2.3 Gender and orthodontic treatment

In a retrospective study by Ward et al (2006) on the changes in arch width in patients who had received orthodontic treatment and untreated patients, they found that gender

had no statistically significant effect on the data gathered from patients that had received orthodontic treatment and from untreated patients.

2.2.4 Effects of non-extraction and extraction treatment on arch width

2.2.4.1 Mandibular arch width changes during treatment

Inter-canine arch width

Many researchers have reported that the mandibular inter-canine width increases during non-extraction treatment (Shapiro 1974, Gardner and Chaconas 1976, Glenn, Sinclair and Alexander 1987, Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993, Bishara et al 1994, Sadowsky et al 1994, Weinberg and Sadowsky 1996, Kim and Gianelly 2003, Gianelly 2003, Taner et al 2004 and Aksu and Kocadereli 2005). The range of increases reported is between 0.06mm and 2.4mm. Isik et al (2005), however, found a decrease in mandibular inter-canine arch width, with an average decrease of 0.6mm. In these studies the average ages at the start of treatment ranged between 10.9 years and 14.21 years of age. The average treatment periods ranged between 1.6 years and 3 years.

Strang (1940) was of the opinion that the mandibular dental arch dimensions in the inter-canine area were uncompromising, and should not be changed if a stable end result was to be achieved. Shapiro (1974) also concluded that any adjustments in the mandibular dental arch dimensions in the intercanine area showed a strong tendency to relapse and thus this area of the arch should not be changed during treatment.

Bishara et al (1994) found no significant changes for both the non-extraction and extraction treatment groups in the inter-canine area pre- to post-treatment.

Numerous researchers have also reported that the mandibular inter-canine width increases during extraction treatment (Bishara 1973, Shapiro 1974, Gardner and Chaconas 1976, Ho and Kerr 1987, Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993, McReynolds and Little 1991, Bishara et al 1994, Boley et al 2003, Gianelly 2003, Kim and Gianelly 2003, Isik et al 2005 and Aksu and Kocadereli 2005). The range of increases reported is between 0.51mm and 2.2mm. The average ages at the onset of treatment ranged between 11.5 years and 14.3 years in these studies. The average treatment periods ranged between 1.84 years and 3.1 years.

King (1974) believed that if the canines are moved distally into the extraction spaces they may be expanded buccally, but for this expansion the limits of their new distal location must be appreciated.

In a retrospective study of 23 subjects treated with the extraction of four first premolars, Ho and Kerr (1987) found that there was a general trend for a reduction in mean arch dimensions both during and following treatment. An exception was in the inter-canine width which showed slight expansion during extraction treatment, which was lost post-treatment in the mandibular arch but maintained in some cases in the maxillary arch (Ho and Kerr 1987).

In a study of comparable groups of borderline extraction versus non-extraction cases it was found that the inter-canine widths of both arches showed no statistically significant change long-term after extraction and non-extraction treatment (Paquette, Beattie and Johnston 1992). The study consisted of 33 extraction and 30 non-extraction Class 11 division 1 subjects. It was not specified which premolars had been extracted in treatment.

It was found that the average post-treatment mandibular inter-canine dimension was larger in four first premolar extraction than in non-extraction cases (Gianelly 2003).

Inter-premolar arch width

Increases in mandibular inter-premolar width during non-extraction treatment have been described in the literature (Gardner and Chaconas 1976, Weinberg and Sadowsky 1996, Sadowsky et al 1994, Kim and Gianelly 2003, Taner et al 2004 and Isik et al 2005). The range of increases reported is between 0.75mm and 2.96mm for the inter-first premolar and between 0.68mm and 2.8mm for the inter-second premolar widths. In these studies the average ages at the commencement of treatment ranged between 10.9 years and 14.21 years of age. The average treatment periods ranged between 1.8 years and 2.96 years.

Many researchers have reported that mandibular inter-premolar width decreases during extraction treatment (Gardner and Chaconas 1976, Ho and Kerr 1987, Kim and Gianelly 2003 and Isik et al 2005). The range of decreases reported is between 0.95mm and 2.64mm. The average ages at the beginning of treatment ranged between 12.74 years and 14.21 years of age in these studies. The average treatment periods ranged between 1.94 years and 2.34 years.

Isik et al (2005) in their study showed that the mandibular inter-premolar distances decreased due to consolidation of the extraction spaces.

Inter-molar arch width

Increases in mandibular inter-molar width during non-extraction treatment have been extensively reported in the literature (Shapiro 1974, Gardner and Chaconas 1976, Glenn, Sinclair and Alexander 1987, Paquette, Beattie and Johnston 1992, Sadowsky et al 1994, Bishara et al 1994, Weinberg and Sadowsky 1996, Kim and Gianelly 2003, Taner et al 2004, Isik et al 2005 and Aksu and Kocadereli 2005). The range of increases reported is between 0.13mm and 3.5mm. Luppanapornlap and Johnson (1993) and Gianelly (2003), however, found a decrease in mandibular inter-molar arch width, with an average decrease between 0.13mm and 0.2mm. The average ages at the outset of treatment

ranged between 10.9 years and 14.21 years in these studies. The average treatment periods ranged between 1.6 years and 3 years.

Strang (1940) believed that the mandibular dental arch dimensions in the inter-molar area were uncompromising dimensions.

Taner et al (2004) found that the mandibular inter-molar arch width showed an increase, but much less than did the maxillary arch. As all the patients in the study were Class 11 non-extraction patients, the significant increase in maxillary arch width is inevitable as maxillary arch expansion is usual in the correction of Class11 patients (Taner et al 2004).

On the other hand Gianelly (2003) found the mandibular inter-molar widths of both non-extraction and extraction groups were essentially unchanged during treatment.

Weinberg and Sadowsky (1996) studied 30 Class1 non-extraction patients. Their study was to determine the manner in which mandibular crowding was resolved in Class 1 growing patients, and found that the molars showed no anteroposterior movement.

Many articles in the literature have described decreases in mandibular inter-molar width during extraction treatment (Shapiro 1974, Gardner and Chaconas 1976, Ho and Kerr 1987, Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993, McReynolds and Little 1991, Bishara et al 1994, Shearn and Woods 2000, Boley et al 2003, Gianelly 2003, Kim and Gianelly 2003, Isik et al 2005 and Aksu and Kocadereli 2005). The range of decreases reported is between 0.6mm and 2.8mm for cases having had mandibular first premolar extractions and between 2.1mm and 4.4mm for those having mandibular second premolar extractions. In these studies the average ages at the beginning of treatment ranged between 11.5 years and 14.3 years. The average treatment periods ranged between 1.84 years and 3.1 years.

The treatment effects of mandibular first and mandibular second premolar extractions were evaluated in a study of 73 patients by Shearn and Woods (2000). According to their

study there was evidence that mandibular second premolar extractions were associated with more reduction in inter-molar arch width than were cases having mandibular first premolar extractions. Their study also showed that there was generally more forward movement of the lower molars than incisal retraction with the extraction of lower second premolars, although a specific extraction pattern does not necessarily guarantee certain amounts of incisor retraction or lower molar forward movement.

Shapiro (1974) also concluded that the mandibular dental arch dimensions in the inter-molar area showed a strong tendency to relapse and thus should not be changed during treatment. Isik et al (2005) in their study also showed that the lower inter-molar distances decreased due to consolidation of the extraction spaces. Bishara et al (1994) found that the inter-molar widths were significantly different between extraction and non-extraction groups as extractions led to a decrease in width in the inter-molar area.

2.2.4.2 Maxillary arch width changes during treatment

Inter-canine arch width

Several published papers have described maxillary inter-canine width increases during non-extraction treatment (Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993, Bishara et al 1994, Sadowsky et al 1994, Kim and Gianelly 2003, Taner et al 2004, Isik et al 2005 and Aksu and Kocadereli 2005). The range of increases reported is between 0.5mm and 3.1mm. The average ages at the start of treatment ranged between 10.9 years and 14.21 years in these studies. The average treatment periods ranged between 1.84 years and 3.1 years.

When Isik et al (2005) evaluated their studies of three treatment modalities, non-extraction patients, non-extraction with rapid maxillary expansion patients and extraction of four first premolars patients, the results revealed that the distance between the upper canines was not affected by the treatment modality.

Increases in maxillary inter-canine width during extraction treatment have been extensively reported by many researchers (Bishara 1973, Ho and Kerr 1987, Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993, Bishara et al 1994, Boley et al 2003, Kim and Gianelly 2003, Isik et al 2005 and Aksu and Kocadereli 2005). The range of increases reported is between 0.8mm and 3.2mm. In these studies the average ages at the initiation of treatment ranged between 12 years and 14.3 years. The average treatment periods ranged between 1.84 years and 3.1 years.

Inter-premolar arch width

Many researchers have reported increases in maxillary inter-premolar width during non-extraction treatment (Sadowsky et al 1994, Kim and Gianelly 2003, Taner et al 2004 and Isik et al 2005). The range of increases reported is between 2.15mm and 4.33mm for the inter-first premolar and between 2.11mm and 4.6mm for the inter-second premolar width. The average ages at the outset of treatment ranged between 10.9 years and 14.21 years in these studies. The average treatment periods ranged between 1.86 years and 3 years.

Isik et al's (2005) study showed that the maxillary inter-premolar widths increased more in the non-extraction sample compared with the extraction sample.

Researchers report that maxillary inter-premolar width decreases during extraction treatment (Kim and Gianelly 2003). The average decrease reported is 0.76mm. Ho and Kerr (1987), Isik et al (2005), however, found an increase in maxillary inter-premolar arch width, with an average expansion of between 0.03mm and 0.44mm. In these studies the average ages at the beginning of treatment ranged between 12.74 years and 13.51 years. The average treatment periods ranged between 1.94 years and 2.34 years.

Inter-molar arch width

Many articles in the literature have described that maxillary inter-molar width increases during non-extraction treatment (Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993, Bishara et al 1994, Sadowsky et al 1994, Kim and Gianelly 2003, Taner et al 2004, Isik et al 2005 and Aksu and Kocadereli 2005). The range of increases reported is between 1.2mm and 5.4mm. The average ages at the start of treatment ranged between 10.9 years and 14.21 years in these studies. The average treatment periods ranged between 1.6 years and 3 years.

Aksu and Kocadereli (2005) studied arch width changes in Class1 patients with extraction and non-extraction orthodontic treatment. Their study consisted of 30 extraction and 30 non-extraction patients. They found that maxillary and mandibular inter-molar widths were significantly greater in the non-extraction group than the extraction group.

Isik et al's (2005) study also showed that the maxillary inter-molar widths increased more in the non-extraction sample compared with the widths in the extraction sample.

Decreases in maxillary inter-molar width during extraction treatment have been reported in the literature (Ho and Kerr 1987, Luppanapornlap and Johnson 1993, Bishara et al 1994, Boley et al 2003, Kim and Gianelly 2003, Isik et al 2005 and Aksu and Kocadereli 2005). The range of decreases reported is between 0.53mm and 2.14mm. Bishara et al (1994), however, found the maxillary inter-molar width in their female extraction sample to be unchanged, and Paquette, Beattie and Johnston (1992) found an increase in average maxillary intermolar width of 0.1mm. The average ages at the start of treatment ranged between 11.5 years and 14.3 years in these studies. The average treatment periods ranged between 1.84 years and 3.1 years.

Kim and Gianelly (2003) studied the arch width and smile aesthetics on 30 patients who had received non-extraction treatment and 30 who had had their four first premolars

extracted. The results of this study indicated that arch width is not decreased at a constant arch depth because of extraction treatment.

2.3 Arch length

2.3.1 Arch length changes during normal growth

Nance (1947) showed that there was a decrease in arch length in the transition from the primary to the permanent dentition.

In a longitudinal study of untreated individuals it was determined in the study that the arch length decreased from the age of 12 to 26 with an average loss of 3.2mm in males and 2.3mm in females (DeKock 1972). Sinclair and Litlle (1983) found that the arch length as well as the intercanine width of untreated individuals with normal occlusion decreased into early adulthood in untreated individuals.

Warren and Bishara (2001) studied a sample of contemporary children in the deciduous dentition and compared that data with a historical sample from about 50 years ago. The sample was the same in terms of geographic area as well as socioeconomic status. In this study it was clear that the maxillary and mandibular arch lengths were significantly shorter in the contemporary children. Warren and Bishara (2003) did a follow up study and found that the tooth sizes in contemporary children are generally similar but with a tendency to be slightly larger when compared with those of children in the historical sample. From these findings it seems that crowding is more common and severe in contemporary children when compared with a similar sample of children but born half a century earlier.

2.3.2 Effect of non-extraction and extraction treatment on arch length

2.3.2.1 Mandibular arch length changes during treatment

Increases in mandibular arch length have been reported during non-extraction treatment (Glenn, Sinclair and Alexander 1987, Paquette, Beattie and Johnston 1992, Sadowsky et al 1994 and Heiser et al 2004,). The range of increase reported is between 0.2mm and 2.9mm. Luppanapornlap and Johnson (1993) and Shapiro (1974), however, found a decrease in average mandibular arch length with the range of decreases reported between 0.2mm and 0.7mm. The average ages at the beginning of treatment ranged between 10.9 years and 12.6 years in these studies. The average treatment periods ranged between 1.6 years and 2.96 years.

Many researchers report that mandibular arch length decreases during extraction treatment (Shapiro 1974, McReynolds and Little 1991, Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993 and Shearn and Woods 2000, Heiser et al 2004). The range of decreases reported is between 8.3mm and 12.1mm. Shearn and Woods (2000) showed that with mandibular first premolar extractions the arch length decreased 11.1mm. Shearn and Woods (2000) and McReynolds and Little (1991) showed that with mandibular second premolar extractions the range of arch length decreases reported was between 11mm and 11.6mm. Ho and Kerr (1987) used a different method to determine the arch length and found a decrease of 3.36mm. In this study only one measurement was used, which was a measurement from the contact points of the incisors to the midpoint of a line connecting the distal contact points of the first molars. Boley et al (2003) measured the arch length as from a point between the central incisors to the midpoint of a line between the mesial contacts of the first molars and found a mandibular arch length decrease of 4.6mm. In these studies the average ages at the beginning of treatment ranged between 12.53 years and 13.9 years. The average treatment periods ranged between 1.84 years and 2.7 years.

2.3.2.2 Maxillary arch length changes during treatment

Researchers report that the maxillary arch length increases during non-extraction treatment (Paquette, Beattie and Johnston 1992 and Heiser et al 2004). The average increases reported are between 1.7mm and 3.2mm. Luppanapornlap and Johnson (1993) and Sadowsky et al (1994), however, reported a decrease in average maxillary arch length of between 0.1mm and 0.9mm. The average ages at the start of treatment ranged between 10.9 years and 12.6 years in these studies. The average treatment periods ranged between 1.6 years and 2.96 years.

Sadowsky et al (1994) in their study found that in non-extraction patients the maxillary arch lengths decreased slightly and the mandibular arch length increased slightly during treatment.

Many articles in the literature have described maxillary arch length decreases during extraction treatment (Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993 and Heiser et al 2004). The range of decreases reported was between 8.3mm and 11.6mm. Ho and Kerr (1987) used a different method to determine the arch length and found a decrease of 4.93mm, whilst Boley et al (2003), also using a different technique found a maxillary arch length decrease of 6.5mm. For these studies the average ages at the beginning of treatment ranged between 12.53 years and 13.7 years. The average treatment periods ranged between 1.84 years and 1.94 years.

According to the study by Boley et al (2003) the arch lengths decrease during treatment because of molar protraction and incisor retraction.

2.4 Summary

Many articles in the literature have shown that arch dimensional changes occur during non-extraction and extraction orthodontic treatment. The literature has shown distinct differences between the effects of extraction and non-extraction treatment. However, considerable variation is seen in the data reflecting changes. Further investigations are warranted. The reported effects of non-extraction and extraction treatment on arch width and arch length from some articles in the literature are summarized in Table 1.

Table 1
Summary of some studies in the literature on the arch width changes in the inter-canine, inter-premolar and inter-molar areas, as well as arch length changes, in the maxilla (Mx) and mandible (Md) during non-extraction orthodontic treatment.

Publication & Year	Treatment groups	Average age At start (years)	Average treat period (years)	Male/ Female	Sample size	Inter-canine width (mm changes)		Inter-premolar Width (mm changes)		Inter-molar Width (mm changes)		Arch length (mm changes)	
						Mx	Md	Mx	Md	Mx	Md	Mx	Md
Isik et al (2005)	NE	14.21			42	1.42	-0.6	1st 2.15 2nd 2.11	1st 0.75 2nd 0.68	1.58	1.12		
Aksu and Kocadereli (2005)	NE	14.1	2.23		30	0.85	1.02			1.45	0.59		
Taner et al (2004)	NE	11.7	3		21	2.52	0.06	1st 4.33 2nd 3.95	1st 1.97 2nd 2.15	3.35	2.31		
Heiser et al (2004)	NE	11.4	1.9		22							3.27	0.59
Gianelly (2003)	NE						0.69				-0.13		
Kim and Gianelly (2003)	NE		1.86		30	0.55	0.43	2.1	1.62	1.53	0.81		
Weinberg and Sadowsky (1996)	NE				30		0.9		1st 1.6 2nd 1.8		1.2		
Bishara et al (1994)	NE				46								
		12.1	2.3	M		0.5	1.0			1.2	0.7		
		10.9	2.3	F		1.5	0.5			1.8	0.5		
Sadowsky et al (1994)	NE	10.9	2.96		22	3.1	2.4	1st 3 2nd 4.6	1st 2.8 2nd 2.8	5.4	3.5	-0.1	0.6
Luppanapornlap and Johnson (1993)	NE				29	0.9	0.9			1.7	-0.2	-0.9	-0.2

Paquette , Beattie and Johnston (1992)	NE	12.60	1.6		30	0.8	1.1			2.8	1.8	1.7	2.9
Glenn, Sinclair and Alexander (1987)	NE				28		0.6				0.9		0.2
Gardner and Chaconas(1976)	NE				74		1.23		1st 2.96 2nd 1.8		2.04		
Shapiro (1974)	NE						0.7				1.4		-0.7

NE: Non-extraction
M: Male
F: Female
Mx: maxilla
Md: mandible

Table 2
Summary of some studies in the literature on the arch width changes in the inter-canine, inter-premolar and inter-molar areas, as well as arch length changes, in the maxilla (Mx) and mandible (Md) during extraction orthodontic treatment.

Publication & Year	Treatment groups	Average age At start (years)	Average treat period (years)	Male/ Female	Sample size	Inter-canine width (mm changes)		Inter-premolar Width (mm changes)		Inter-molar Width (mm changes)		Arch length (mm changes)	
						Mx	Md	Mx	Md	Mx	Md	Mx	Md
Isik et al (2005)	4's	13.57			27	1.72	0.61	0.03	-2.64	-0.88	-1.42		
Aksu and Kocadereli (2005)	EXT	14.3	2.32		30	1.47	1.63			-2.14	-0.93		
Heiser et al (2004)	EXT	13.7	1.9		20							-9.64	-12.1
Boley et al (2003)	EXT	12.8	2.7		32	1.0	1.7			-1.7	-2.1	-6.5	-4.6
Gianelly (2003)	EXT						1.39				-1.54		
Kim and Gianelly (2003)	4's		2.34		30	0.84	0.51	-0.76	-0.95	-0.53	-0.94		
Shearn and Woods (2000)	Md 1st	13.6	2.3								-2.8		-11.1
	Md 2nd	13.9	2.2								-4.4		-11.6
Bishara et al (1994)	4,s				45								
		11.5	3.1	M		3.2	1.7			-0.9	-1.9		
		11.6	2.9	F		2.4	1.9			unchanged	-1.0		
McReynolds and Little (1991)	Md 2nd	12.6	2.7				0.7				-2.1		-11
Luppanapornlap and Johnson (1993)	EXT				33	1.2	1.6			-0.7	-2.5	-8.3	-8.6

Paquette , Beattie and Johnston (1992)	EXT	12.53	1.84		33	0.8	2.2			0.1	-0.6	-11.6	-9.1
Ho and Kerr (1987)	EXT	12.74	1.94		23	0.92	0.57	0.44	-1.07	-0.76	-1.04	-4.93	-3.36
Gardner and Chaconas (1976)	4's				29		1.92		-2.34		-1.46		
Shapiro (1974)	EXT						1.7				-1.0		-8.3
Bishara (1973)	4's	12	2.8		30	3.1	0.77						

EXT: Extraction
4's: Extraction of maxillary and mandibular first premolars
Md 1st Extraction of mandibular first premolars
Md 2nd Extraction of mandibular second premolars
M: Male
F: Female
Mx: maxilla
Md: mandible

Chapter 3

Research design and methodology

3.1 Aims and Objectives

The aim of this study was to determine the effect of non-extraction and premolar extraction orthodontic treatment on interdental widths and arch lengths in the maxillary and mandibular dentitions. The results of three treatment modalities were assessed and the data analyzed statistically.

The objectives were to determine whether;

1. The dental arch widths and arch lengths increased during non-extraction treatment.

2. The dental arch widths and arch lengths decreased when premolar extractions are done.

3. There were any differences in the dental arch widths and arch lengths with different premolar extraction patterns.

3.2 Sample description

Three groups of patients treated by one orthodontist were selected; a non-extraction group (Group NE), a group where the upper and lower first premolars were extracted (Group 44) and a group which had extractions of the upper first and lower second premolars (Group 45). The patients were randomly selected within the categories of non-extraction and extraction treatment. The total sample consisted of 78 patients. The pre- and post-treatment study models of 26 patients in each of the three treatment groups were analyzed. Each group had an equal number of males and females (13 males and 13 females).

The study was not limited to a certain malocclusion, and the three groups had the following division of patients.

Table 3

Illustration of the breakdown of the types of malocclusions in each of the study sample groups.

Groups	Class I	Class 11 division 1	Class I1 division 2	Total
Group NE	16	5	5	26
Group 44	20	3	3	26
Group 45	3	15	8	26

The inclusion criteria were

- Complete pre-treatment and immediate post-treatment study models of both the maxillary and mandibular arches were available.
- All patients had received full fixed appliance treatment.
- Cases had to have a full complement of teeth exclusive of third molars. No permanent teeth were missing, unless they were the premolars that were designated to be extracted as part of the orthodontic treatment. Premolars designated for extraction had to be present in the pre-treatment study models.

The exclusion criteria were

- The presence of any dental anomalies e.g., congenitally missing premolars.
- Patients with cleft lip and/or palate deformities.
- Patients with craniofacial deformities and or any craniofacial syndromes.
- Patients who had been treated with removable or fixed expansion appliances.

3.3 Arch width measurement

The arch widths in both the mandibular and maxillary arches were measured. The pre-treatment maxillary and mandibular values as well as post-treatment maxillary and mandibular values were measured in the inter-canine, inter-first and/ or inter-second premolar and the inter-molar regions.

The arch widths were measured using a MAX-CAL electronic digital caliper[1] (Fig 1). The distances between the most convex buccal surfaces of the canines, most convex buccal surfaces of the premolars and most convex buccal surfaces at the buccal groove of the molars were used to measure the arch widths in each dental arch (Fig 2), according to methods described by Gardner and Chaconas (1976), Gianelly (2003) and Aksu and Kocadereli (2005). The caliper was placed at the bucco-gingival margins of the canines, premolars and first molar. The technique used in this study was selected to determine the widest possible widths of the arches. The method where the cusp tips and grooves of teeth were used to measure inter-tooth distances was not an option for us to use. Some patients had teeth with restorations, which had changed the anatomy of the teeth, therefore this method proved to be difficult to use (Bishara et al 1997, Walkow & Peck 2002).

Pre- and post-treatment arch widths were measured. Each measurement, for the inter-canine, inter-premolars and inter-molar arch widths, was repeated three times on three separate days. The mean of the three values for each parameter was then calculated. The data was captured on a separate form for each patient (Appendix A).

The data was entered onto a Microsoft Excel spreadsheet and statistically analyzed.

[1] MAX-Series electronic digital Caliper with a resolution of 0, 01mm, Fowler & NSK, made in Japan.

Figure 1
MAX-CAL electronic digital caliper. MAX-Series electronic digital Caliper with a resolution of 0, 01mm, Fowler & NSK, made in Japan.

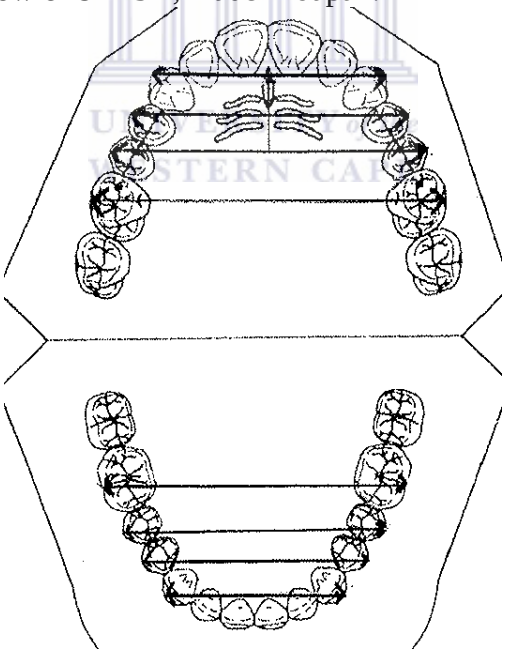

Figure 2:Inter-canine width: distance between most convex point on the buccal surfaces of the canines.
Inter-premolar width: distance between most convex point on the buccal surfaces of the premolars.
Inter-molar width: distance between the most convex point on the buccal surfaces at the buccal groove of the first molars. (Gardner and Chaconas 1976, Gianelly 2003, and Aksu and Kocadereli 2005).

3.4 Arch length measurement

The arch length was calculated by measuring the sum of the left and right distances from mesial anatomic contact points of the first permanent molars to the contact point of the central incisors or to the midpoint of the distance between the contact points if the incisors were spaced, Little and Riedel (1989) (Fig 3). The arch lengths in both mandibular and maxillary arches were measured using the MAX-CAL electronic digital caliper.

Pre- and post-treatment arch lengths were measured and each measurement was repeated three times on three separate days. The mean of the three values was then calculated. The data was captured on a separate form for each patient (Appendix A).

The data was entered onto a Microsoft Excel spreadsheet and statistically analyzed.

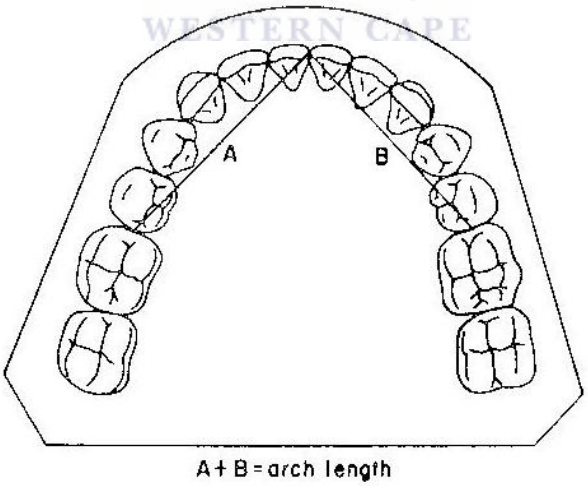

Figure 3.Arch length is measured as the sum of the right and left distances from mesial anatomic contact points of the first permanent molars to the contact point of the central incisors or to the midpoint of the distance between the central incisor contacts, if the teeth were spaced (Little and Riedel 1989).

3.5 Analysis of data

3.5.1 Pilot study

The pre-and post-treatment arch widths and arch lengths of ten patients were measured at three different times, and the mean of the three values calculated for each patient.

Standardized error

These ten pairs of triplet measurements were analyzed for their accuracy.

The difference between the minimum and the maximum values is considered to be the error. This error was standardized by means of taking the average of the three repeated measurements. The standardized error is the range of the three repeats divided by their average, and is expressed as a percentage. The medians of the standardized error for the pre- and post-treatment arch width measurements ranged between 0.087% and 0.635%. The maximum standardized errors for the pre- and post-treatment arch width measurements varied between 0.298% and 1.700%. The medians of the standardized error for the pre- and post-treatment arch length measurements ranged between 0.452% and 1.225%. The maximum standardized errors for the pre- and post-treatment arch length measurements varied between 1.190% and 3.419%. The maximum standardized error was found to be in an acceptable range.

The intra-observer variability was found to be within an acceptable range.

3.5.2 Statistical Methods applied

Univariate exploratory data analysis was applied to all the measurements to detect unusual values or even data errors. The data mistakes were identified by checking the minimum and maximum values of each subgroup. After correcting such mistakes the descriptive statistics were tabulated for the three groups.

For the data gathered from the mandible and the maxilla, descriptive statistics, including the mean, standard deviation, minimum and maximum, were calculated. These measurements were calculated for all three groups of treatment modalities.

The changes between pre- and post-treatment measurements were calculated for each patient for each method. Thereafter sum versus difference plots were generated in order to gain insight into the bi-variate distribution. These measures of change were tested, studied and statistical inference was applied to the results.

The Wilcoxon signed rank test was used to test whether there were statistically significant changes in the arch widths within the three treatment groups. This was done for the inter-canine, inter-premolar and inter-molar arch widths in both the pre-treatment and post-treatment groups.

The Kruskal-Wallis test was used to compare any changes in arch width for the two extraction groups, and to identify any significant difference between these data. The Kruskal-Wallis test was used to compare the change in the arch widths of the three groups. A p-value less than 0.05 was considered to be significant.

The correlation coefficient between the changes in arch width was also studied. All values above 0.6 were considered significant.

In the same manner, the descriptive statistics, Wilcoxon signed rank test, Kruskal-Wallis test and correlation coefficient were also used for statistical analysis of the arch length data, to determine whether there were changes within the three treatment groups from pre- to post-treatment stages, and whether there was a difference between the data of the two extraction groups.

3.6 Ethics statement

This study did not involve any clinical procedures on patients. The patients included in this study were not identifiable from the records that were used.

Chapter 4

RESULTS

4.1 Age comparison and average treatment period

Figures 4, 5 and 6 show the distribution of age of the patients when treatment was started in Group NE, Group 44 and Group 45 respectively. The average ages of the patient at the start of treatment differed between the non-extraction group and the two extraction groups. Treatment in Group NE started earlier than in the two extraction groups, the average age at start of treatment being 13.73 years (Table 4).

A summary of the average ages at the start of treatment and the treatment periods for the three groups of patients is presented in Table 4. Treatment took longer than one year in all three treatment groups. In Group NE most treatments took less than 2 years. In a few cases, however, the treatment lasted a little over 2 years and in one case the treatment period was nearly 3 years (Figure 4). The average treatment period for Group NE was 1.84 years. (One case having an age of 28.8 years at start of treatment was excluded from Figure 4, but included in the analysis).

The grouping for both extraction groups showed that treatment usually lasted around 2 years. In Group 44 the treatment lasted on average 1.97 years and in Group 45 lasted 2.29 years on average (Table 4). Group 44 (Figure 5) showed a nearly equal distribution of patients for whom treatment was less than 2 years and of patients in whom the treatment was longer than 2 years. For Group 44 the average age at start of treatment was 13.93 years (Table 4).

Group 45 had the longest treatment period with an average treatment duration of 2.29 years (Table 4). In three cases the treatment lasted longer than 3 years (Figure 6). For Group 45 the average age at start of treatment was 14.62 years (Table 4). Excluded from

Figure 6 were one case who was 22.1years of age at start of treatment and one recording a treatment period of 5.29 years.

There were no statistically significant differences ($p>0.05$) between the means when the ages at the start of treatment were compared, nor when the treatment periods were compared, between the three groups of treatment (Table 38).

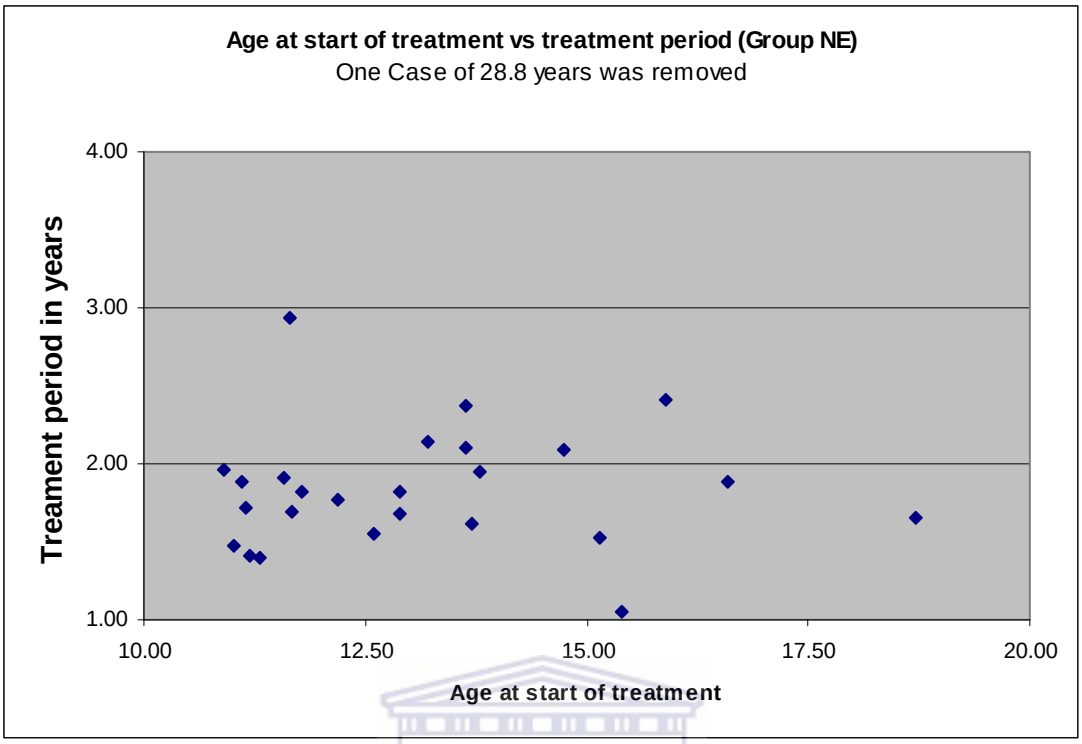

Figure 4
Starting age of treatment vs. treatment period (Group NE) (One case of 28.8 years at start of treatment was excluded from this graph).

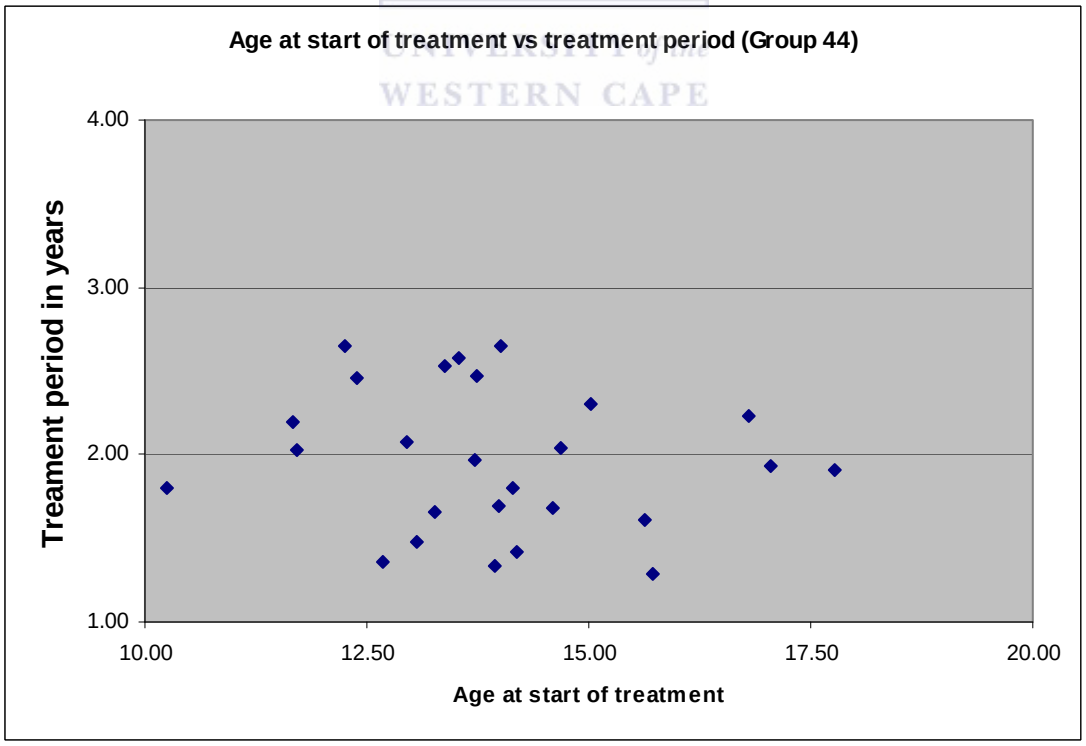

Figure 5
Starting age of treatment vs. treatment period (Group 44).

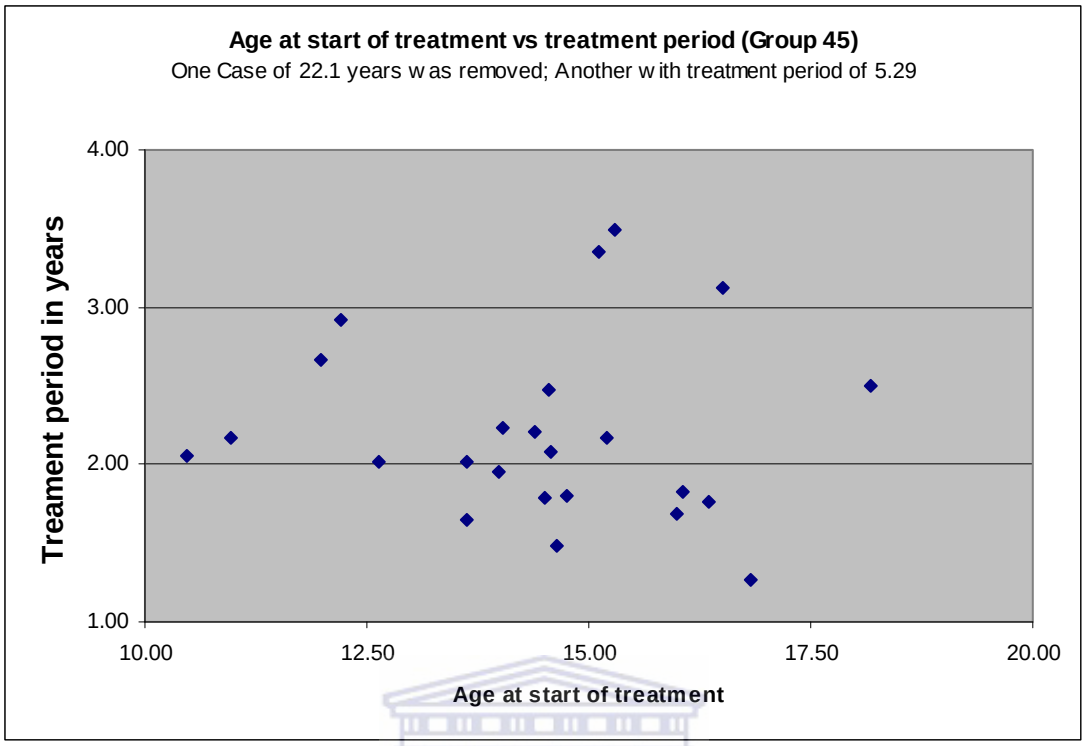

Figure 6
Starting age of treatment vs. treatment period (Group 45). (One case with age 22.1years at start of treatment and another with a treatment period of 5.29 years were excluded from this graph).

Table 4
Average, standard deviation and median of the age at start of treatment and treatment period for the three treatment groups.

Treatment groups	Average *age(years)* at the start of treatment	Standard deviation (SD) of *age(years)*	Median of *age(years)* at the start of treatment	average treatment *period (years)* and standard deviation (SD) (years)	standard deviation (SD) of treatment *period (years)*	Median of treatment *period (years)* and standard deviation (SD) (years)
Nonextraction (Group NE) (Males & Females)	13.73	3.66	12.9	1.84	0.38	1.8
Males (Group NE)	13.11	2.30	11.8	1.84	0.43	1.7
Females (Group NE)	14.37	4.67	13.2	1.84	0.34	1.9
Extraction of four first premolars (Group 44) (Males & Females)	13.93	1.72	13.8	1.97	0.43	1.9
Males (Group 44)	13.94	1.59	13.7	2.15	0.39	2.2
Females (Group 44)	13.92	1.91	14.0	1.78	0.39	1.7
Extraction of upper first and lower second premolars (Group 45) (Males & Females)	14.62	2.39	14.6	2.29	0.83	2.1
Males (Group 45)	14.08	2.32	14.6	2.27	0.99	2.1
Females (Group 45)	15.17	2.43	14.8	2.31	0.67	2.0

The associated standard deviation is likely to be affected in the case where the average and the median are substantially different (medians highlighted) in the sense that the standard deviation would be larger than expected.

4.2 Arch width

The descriptive statistics for the pre- and post-treatment values of the inter-canine, inter-first premolar, inter-second premolar and inter-molar arch widths for the mandible and maxilla for the three treatment groups are presented in Tables 5-20.

4.2.1 Comparison of arch widths measured on pre-treatment study models.

4.2.1.1 Mandibular arch

a) Males compared with females (*Tables 5, 7, 9, 11)*

The average inter-canine, inter-first premolar, inter-second premolar and inter-molar arch widths in the males were larger in Group NE and Group 45 than the corresponding arch widths of the females. In the Group 44, the females had slightly larger average arch widths in the inter-canine, inter-first premolar, inter-second premolar and inter-molar area.

Inter-canine arch width: *Table 5*

The inter-canine arch width in the female sample showed similar values for Group NE and Group 45. The average arch width was +/- 0.8mm more in Group 44 compared with the other two groups. In the male sample Group 44 had the smallest average arch width, with Group NE an average of 0.62mm larger and Group 45 was an average of 1.34mm larger than the first group.

Inter-first premolar arch width: *Table 7*

The inter-first premolar arch width of the female group showed similar values for Group NE and Group 45. The female sample of Group 44 showed a larger average arch width of +/- 0.85 mm. The male group showed similar values for Group NE and Group 45. In the

male sample the average arch width was +/- 0.83 less in Group 44 compared with the other two groups.

Inter-second premolar arch width: *Table 9*

The inter-second premolar arch width for the female group showed almost similar values for the two extraction groups. The average arch width in Group NE was +/- 0.81mm larger compared with the two extraction groups for the female sample. In the male sample the average arch width was the widest in Group NE, with Group 45 an average of 0.43mm less and Group 44 an average of 2.22mm less compared with the non-extraction group.

Inter-molar arch width: *Table 11*

For the inter-molar arch width the female sample in Group 44 had the largest average arch width, with Group NE showing an average of 0.67mm less and group 45 an average of 1.14mm less compared with Group 44. In the male sample Group NE and Group 45 had almost similar values. In Group 44 the average arch width in males was +/- 1.31mm less compared with the other two groups.

b) Averages of combined samples for mandibular arch widths

For the combined averages, the pre-treatment values in the mandibular arch showed almost similar values for the three treatment groups, except for the inter-second premolar arch width (Tables 5, 7, 9 and 11). In Group 45 the average inter-second premolar arch width was 0.79mm more than the arch width of Group 44, and in Group NE the average inter-second premolar arch width was 1.51mm more than that of Group 44.

Table 5
Descriptive statistics for the three treatment groups for the mandibular pre-treatment inter-canine arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	30.79	29.99	29.95	30.24
	Standard Deviation	1.64	1.72	1.72	1.69
	Minimum	28.00	26.61	26.65	26.61
	Maximum	34.39	32.37	32.33	34.39
M	Count	13	13	13	39
	Average	30.44	31.78	31.06	31.09
	Standard Deviation	2.40	1.88	1.24	1.93
	Minimum	25.48	28.82	29.48	25.48
	Maximum	35.64	36.23	33.36	36.23
Count of both genders		26	26	26	78
Average		30.61	30.89	30.50	30.67
Standard Deviation		2.02	1.99	1.58	1.86
Minimum		25.48	26.61	26.65	25.48
Maximum		35.64	36.23	33.36	36.23

Table 6
Descriptive statistics for the three treatment groups for the mandibular post-treatment inter-canine arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	32.41	31.32	30.92	31.55
	Standard Deviation	1.12	1.12	1.46	1.37
	Minimum	30.90	29.77	28.08	28.08
	Maximum	34.42	33.47	32.67	34.42
M	Count	13	13	13	39
	Average	32.95	33.46	32.31	32.91
	Standard Deviation	1.59	1.29	1.55	1.52
	Minimum	31.27	30.79	30.49	30.49
	Maximum	36.95	35.09	34.76	36.95
Count of both genders		26	26	26	78
Average		32.68	32.39	31.61	32.23
Standard Deviation		1.37	1.61	1.64	1.59
Minimum		30.90	29.77	28.08	28.08
Maximum		36.95	35.09	34.76	36.95

Table 7
Descriptive statistics for the three treatment groups for the mandibular pre-treatment inter-first premolar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	39.85	39.00	38.77	39.21
	Standard Deviation	2.45	1.89	2.15	2.17
	Minimum	35.88	35.74	35.94	35.74
	Maximum	43.61	42.29	42.85	43.61
M	Count	13	13	13	39
	Average	39.41	40.24	40.34	40.00
	Standard Deviation	2.42	2.94	2.41	2.57
	Minimum	35.85	36.72	36.49	35.85
	Maximum	42.89	45.48	44.80	45.48
Count of both genders		26	26	26	78
Average		39.63	39.62	39.55	39.60
Standard Deviation		2.39	2.50	2.38	2.39
Minimum		35.85	35.74	35.94	35.74
Maximum		43.61	45.48	44.80	45.48

Table 8
Descriptive statistics for the three treatment groups for the mandibular post-treatment inter-first premolar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count		13	13	26
	Average		41.08	40.41	40.74
	Standard Deviation		1.12	1.59	1.39
	Minimum		39.47	36.60	36.60
	Maximum		43.66	43.18	43.66
M	Count		13	13	26
	Average		43.06	41.80	42.43
	Standard Deviation		1.53	1.85	1.78
	Minimum		40.42	39.74	39.74
	Maximum		46.20	45.79	46.20
Count of both genders			26	26	52
Average			42.07	41.10	41.59
Standard Deviation			1.66	1.83	1.80
Minimum			39.47	36.60	36.60
Maximum			46.20	45.79	46.20

Table 9
Descriptive statistics for the three treatment groups for the mandibular pre-treatment inter-second premolar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	44.62	44.41	45.43	44.82
	Standard Deviation	2.73	2.21	2.53	2.47
	Minimum	40.24	40.38	42.50	40.24
	Maximum	49.17	47.08	49.94	49.94
M	Count	13	13	13	39
	Average	44.16	45.95	46.38	45.50
	Standard Deviation	3.11	2.20	2.51	2.74
	Minimum	39.22	41.99	43.51	39.22
	Maximum	48.75	48.32	52.56	52.56
Count of both genders		26	26	26	78
Average		44.39	45.18	45.90	45.16
Standard Deviation		2.88	2.30	2.52	2.62
Minimum		39.22	40.38	42.50	39.22
Maximum		49.17	48.32	52.56	52.56

Table 10
Descriptive statistics for the three treatment groups for the mandibular post-treatment inter-second premolar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13		13	26
	Average	42.90		46.09	44.50
	Standard Deviation	0.87		1.72	2.10
	Minimum	41.47		42.32	41.47
	Maximum	44.40		49.73	49.73
M	Count	13		13	26
	Average	42.55		47.58	45.06
	Standard Deviation	1.34		2.02	3.07
	Minimum	40.74		44.71	40.74
	Maximum	44.88		52.25	52.25
Count of both genders		26		26	52
Average		42.73		46.84	44.78
Standard Deviation		1.12		1.99	2.62
Minimum		40.74		42.32	40.74
Maximum		44.88		52.25	52.25

Table 11
Descriptive statistics for the three treatment groups for the mandibular pre-treatment inter-molar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	52.39	51.25	51.72	51.79
	Standard Deviation	2.10	2.09	2.48	2.22
	Minimum	48.93	47.97	47.90	47.90
	Maximum	54.93	54.88	56.74	56.74
M	Count	13	13	13	39
	Average	51.50	52.81	53.18	52.50
	Standard Deviation	2.49	2.13	2.45	2.41
	Minimum	47.81	49.18	50.29	47.81
	Maximum	55.71	56.93	59.76	59.76
Count of both genders		26	26	26	78
Average		51.95	52.03	52.45	52.14
Standard Deviation		2.30	2.21	2.53	2.33
Minimum		47.81	47.97	47.90	47.81
Maximum		55.71	56.93	59.76	59.76

Table 12
Descriptive statistics for the three treatment groups for the mandibular post-treatment inter-molar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	50.26	48.94	51.76	50.32
	Standard Deviation	1.51	1.64	2.06	2.06
	Minimum	47.58	46.23	48.70	46.23
	Maximum	52.39	51.97	56.86	56.86
M	Count	13	13	13	39
	Average	49.35	50.18	53.51	51.01
	Standard Deviation	1.98	1.93	2.31	2.72
	Minimum	46.22	46.86	50.20	46.22
	Maximum	53.94	53.11	58.93	58.93
Count of both genders		26	26	26	78
Average		49.80	49.56	52.63	50.67
Standard Deviation		1.78	1.86	2.32	2.43
Minimum		46.22	46.23	48.70	46.22
Maximum		53.94	53.11	58.93	58.93

4.2.1.2 Maxillary arch

a) Males compared with females (Tables 13, 15, 17 and 19)

The average maxillary arch widths for all three treatment groups were larger in the males in the inter-canine and inter-second premolar areas. In Group NE and Group 45 the males also had a larger average arch width in the inter-second premolar and inter-molar areas compared with the females. Group 44 showed a slightly larger average arch width for the females in the inter-second premolar and inter-molar region (Tables 13, 15, 17 and 19).

Inter-canine arch width: *Table 13*

The average arch width of Group NE and Group 45 showed similar values in the female groups. In the female sample of Group 44 the average arch width was +/-2mm larger compared with the other two groups. In the male sample the three treatment groups had similar values.

Inter-first premolar arch width: *Table 15*

The female sample had a greater average arch width in Group 44 compared with the other groups. Group NE had an average arch width of 1.45mm less and Group 45 showed an average of 2.69mm smaller arch width compared with Group 44. The males had similar values for the three treatment groups.

Inter-second premolar arch width: *Table 17*

The female sample had a greater average arch width in Group 44 compared with the other groups. Group NE had an average arch width of 1.28mm less and Group 45 had an average of 2.41mm less arch width compared with Group 44. The males in Group NE and Group 44 had similar values. In males Group 45 had an average arch width +/-0.6mm smaller compared with the other two groups.

Inter-molar arch width: *Table 19*

The female sample had a greater average arch width in Group 44 compared with the other groups. Group NE had an average arch width of 2.23mm less and Group 45 had an average of 2.86mm less arch width compared with Group 44. The males had similar values for the two extraction groups. Group NE showed an average arch width of +/- 0.5mm more compared with the two extraction groups in the male sample.

b) Averages of combined samples for maxillary arch widths

Inter-canine arch width: *Table 13*

For the maxillary arch the average pre-treatment inter-canine arch width showed similar values for Group NE and Group 45. In Group 44 the average arch width was +/- 1mm greater compared with both the other groups.

Inter-first premolar arch width: *Table 15*

The average pre-treatment inter-first premolar arch width for the maxilla was the greatest in Group 44. The average arch width for Group 45 was 1.51mm less and 0.81mm less in Group NE compared with Group 44.

Inter-second premolar arch width: *Table 17*

The average pre-treatment inter-second premolar arch width in the maxilla was the greatest in Group 44. For Group 45 the average arch width was 1.48mm less and 0.61mm less in Group NE compared with Group 44.

Inter-molar arch width: *Table 19*

The average pre-treatment inter-molar arch width in the maxilla was the greatest in Group 44. The average arch width for Group 45 was 1.47mm less and 0.88mm less in Group NE compared with Group 44.

Table 13
Descriptive statistics for the three treatment groups for the maxillary pre-treatment inter-canine arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	38.76	36.77	36.78	37.44
	Standard Deviation	2.08	2.28	3.03	2.61
	Minimum	36.34	32.32	32.77	32.32
	Maximum	42.91	41.32	41.99	42.91
M	Count	13	13	13	39
	Average	38.95	38.98	38.65	38.86
	Standard Deviation	2.90	1.83	2.40	2.36
	Minimum	31.62	36.60	34.67	31.62
	Maximum	42.06	42.20	43.52	43.52
Count of both genders		26	26	26	78
Average		38.86	37.87	37.72	38.15
Standard Deviation		2.48	2.32	2.84	2.57
Minimum		31.62	32.32	32.77	31.62
Maximum		42.91	42.20	43.52	43.52

Table 14
Descriptive statistics for the three treatment groups for the maxillary post-treatment inter-canine arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	40.54	38.93	38.49	39.32
	Standard Deviation	1.49	1.89	2.13	2.01
	Minimum	37.36	35.80	34.85	34.85
	Maximum	42.51	42.45	41.29	42.51
M	Count	13	13	13	39
	Average	40.86	40.96	39.38	40.40
	Standard Deviation	1.78	1.45	2.97	2.23
	Minimum	37.75	38.08	32.00	32.00
	Maximum	43.70	43.42	43.93	43.93
Count of both genders		26	26	26	78
Average		40.70	39.95	38.93	39.86
Standard Deviation		1.62	1.95	2.57	2.18
Minimum		37.36	35.80	32.00	32.00
Maximum		43.70	43.42	43.93	43.93

Table 15
Descriptive statistics for the three treatment groups for the maxillary pre-treatment inter-first premolar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	45.11	42.42	43.66	43.73
	Standard Deviation	2.47	2.22	3.06	2.77
	Minimum	41.21	39.30	39.60	39.30
	Maximum	50.26	45.83	48.98	50.26
M	Count	13	13	13	39
	Average	44.82	44.34	44.66	44.60
	Standard Deviation	3.11	3.82	2.65	3.15
	Minimum	41.38	37.42	40.32	37.42
	Maximum	50.14	51.91	50.29	51.91
Count of both genders		26	26	26	78
Average		44.97	43.38	44.16	44.17
Standard Deviation		2.76	3.21	2.85	2.98
Minimum		41.21	37.42	39.60	37.42
Maximum		50.26	51.91	50.29	51.91

Table 16
Descriptive statistics for the three treatment groups for the maxillary post-treatment inter-first premolar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count			13	13
	Average			46.02	46.02
	Standard Deviation			2.19	2.19
	Minimum			42.29	42.29
	Maximum			48.77	48.77
M	Count			13	13
	Average			47.59	47.59
	Standard Deviation			2.23	2.23
	Minimum			44.66	44.66
	Maximum			52.00	52.00
Count of both genders				26	26
Average				46.80	46.80
Standard Deviation				2.31	2.31
Minimum				42.29	42.29
Maximum				52.00	52.00

Table 17
Descriptive statistics for the three treatment groups for the maxillary pre-treatment inter-second premolar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	49.33	46.92	48.05	48.10
	Standard Deviation	2.76	2.41	3.23	2.92
	Minimum	45.45	43.74	44.24	43.74
	Maximum	54.32	50.37	55.00	55.00
M	Count	13	13	13	39
	Average	49.62	49.06	49.68	49.45
	Standard Deviation	2.82	4.68	2.88	3.49
	Minimum	46.04	40.85	45.70	40.85
	Maximum	55.60	58.42	56.29	58.42
Count of both genders		26	26	26	78
Average		49.47	47.99	48.86	48.77
Standard Deviation		2.74	3.81	3.11	3.27
Minimum		45.45	40.85	44.24	40.85
Maximum		55.60	58.42	56.29	58.42

Table 18
Descriptive statistics for the three treatment groups for the maxillary post-treatment inter-second premolar arch width measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	48.55	46.65	50.15	48.45
	Standard Deviation	1.74	1.48	2.09	2.26
	Minimum	45.96	44.26	46.45	44.26
	Maximum	51.05	49.20	53.74	53.74
M	Count	13	13	13	39
	Average	48.38	48.75	51.77	49.63
	Standard Deviation	1.59	1.86	2.69	2.56
	Minimum	46.08	45.69	47.92	45.69
	Maximum	51.67	52.17	57.96	57.96
Count of both genders		26	26	26	78
Average		48.47	47.70	50.96	49.04
Standard Deviation		1.64	1.96	2.50	2.47
Minimum		45.96	44.26	46.45	44.26
Maximum		51.67	52.17	57.96	57.96

Table 19
Descriptive statistics for the three treatment groups for the maxillary pre-treatment inter-molar arch width measurement.

		Group 44	Group 45	Group NE	
Gender	Data				Total
F	Count	13	13	13	39
	Average	56.00	53.14	53.77	54.30
	Standard Deviation	3.30	2.21	2.53	2.92
	Minimum	50.71	50.34	50.17	50.17
	Maximum	60.09	57.98	59.57	60.09
M	Count	13	13	13	39
	Average	55.11	55.01	55.57	55.23
	Standard Deviation	2.83	3.30	3.18	3.04
	Minimum	51.11	50.87	51.53	50.87
	Maximum	61.09	61.19	64.83	64.83
Count of both genders		26	26	26	78
Average		55.55	54.08	54.67	54.77
Standard Deviation		3.05	2.91	2.96	3.00
Minimum		50.71	50.34	50.17	50.17
Maximum		61.09	61.19	64.83	64.83

Table 20
Descriptive statistics for the three treatment groups for the maxillary post-treatment inter-molar arch width measurement.

		Group 44	Group 45	Group NE	
Gender	Data				Total
F	Count	13	13	13	39
	Average	54.30	52.21	53.83	53.45
	Standard Deviation	2.83	1.74	2.59	2.53
	Minimum	49.56	49.78	49.93	49.56
	Maximum	58.99	54.38	59.41	59.41
M	Count	13	13	13	39
	Average	53.24	53.77	55.97	54.32
	Standard Deviation	1.91	2.11	3.16	2.67
	Minimum	50.97	50.96	51.09	50.96
	Maximum	57.71	57.64	63.57	63.57
Count of both genders		26	26	26	78
Average		53.77	52.99	54.90	53.89
Standard Deviation		2.42	2.05	3.03	2.62
Minimum		49.56	49.78	49.93	49.56
Maximum		58.99	57.64	63.57	63.57

4.2.2 Pre- and Post-treatment Average vs. Standard Deviation of the three treatment groups for the arch width in the inter-canine and inter-molar areas

Figures 7 to 14 show graphic plots of the average vs. the standard deviation for the inter-canine and inter-molar arch width for the three groups of treatment. The inter-canine and inter-molar arch widths were chosen for this as they were arch widths which were present pre- and post-treatment in all three groups. The inter-premolar arch widths were not chosen as premolars were extracted in two of the treatment groups.

The average inter-canine arch width increased in all three treatment groups in both the mandible and maxilla. The average inter-molar arch width increased slightly in Group NE and decreased in both Group 44 and Group 45 for both the mandible and maxilla.

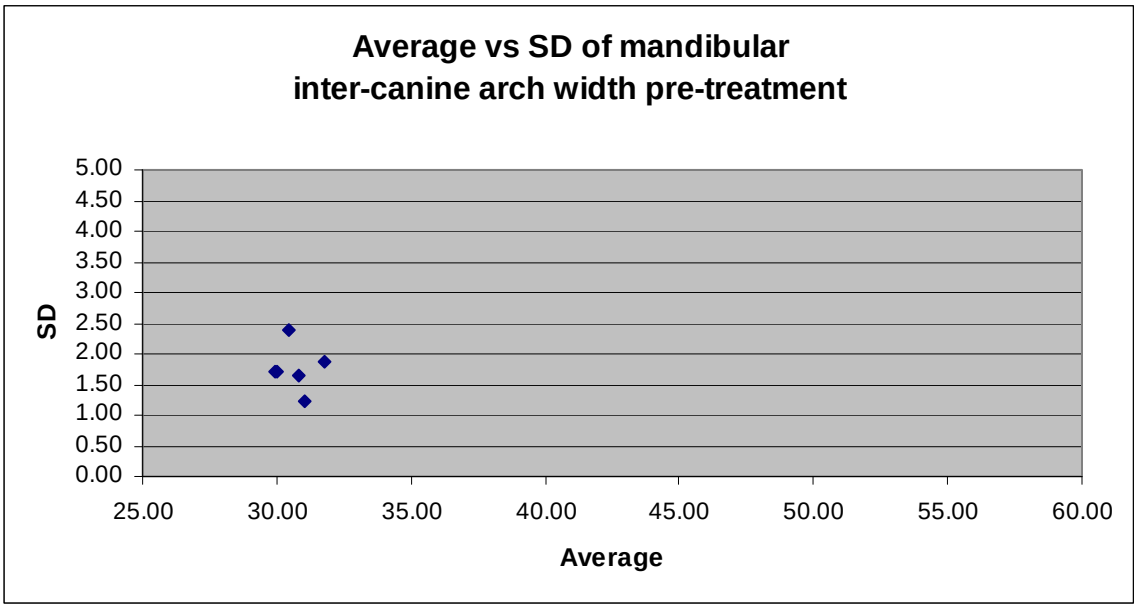

Figure 7

Average vs. the Standard Deviation of the mandibular inter-canine pre-treatment arch width values.

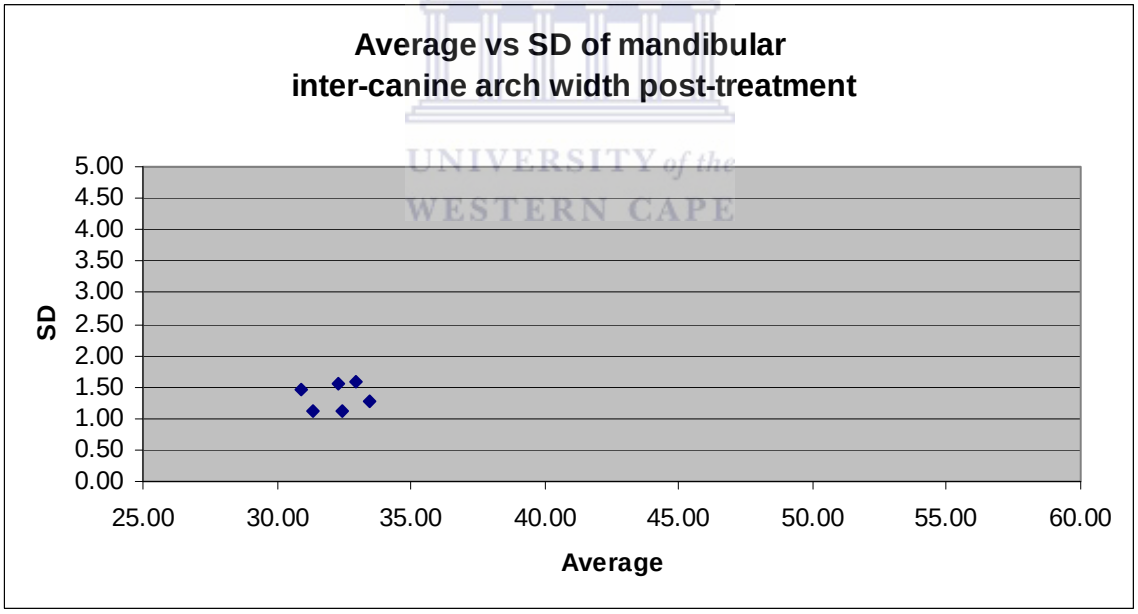

Figure 8

Average vs. the Standard Deviation of the mandibular intercanine post-treatment arch width values.

Figures 7 and 8 show the average vs. the standard deviation for the three treatment groups, and averages for males and females for the mandibular inter-canine pre-treatment and post-treatment values from Tables 5 and 6. The figures show that the average inter-canine arch width increased during treatment in most cases.

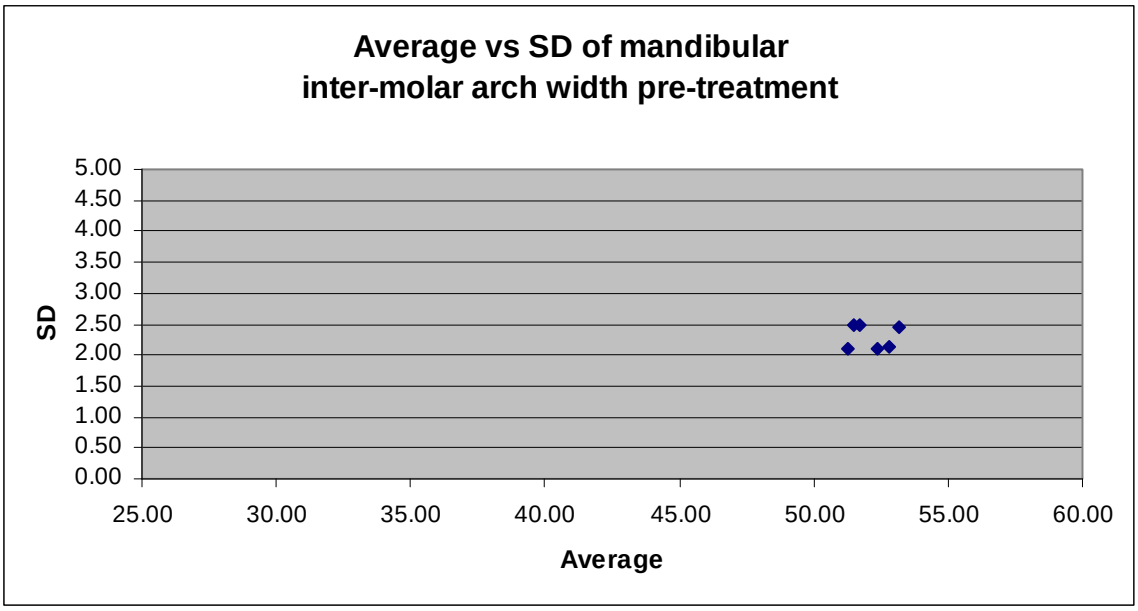

Figure 9
Average vs. the Standard Deviation of the mandibular inter-molar pre-treatment arch width values.

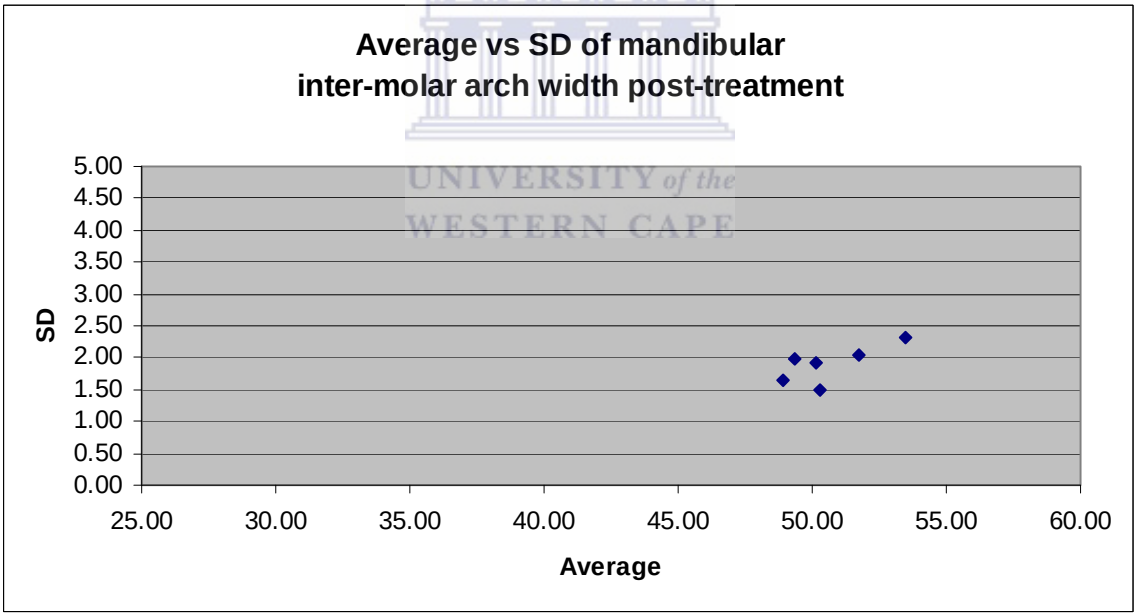

Figure 10
Average vs. the Standard Deviation of the mandibular inter-molar post-treatment arch width values.

Figures 9 and 10 show the average vs. the standard deviation for the three treatment groups, and averages for males and females for the mandibular inter-molar pre-treatment and post-treatment values from Tables 11 and 12. It is evident that there was mainly a decrease in the average inter-molar widths post-treatment.

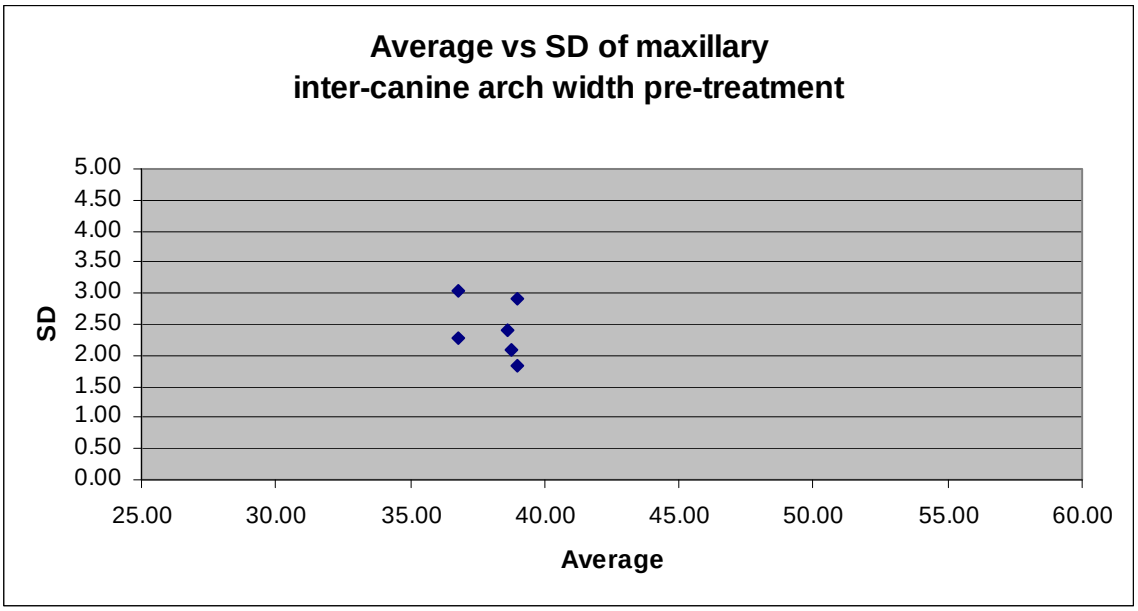

Figure 11
Average vs. the Standard Deviation of the maxillary inter-canine pre-treatment arch width values.

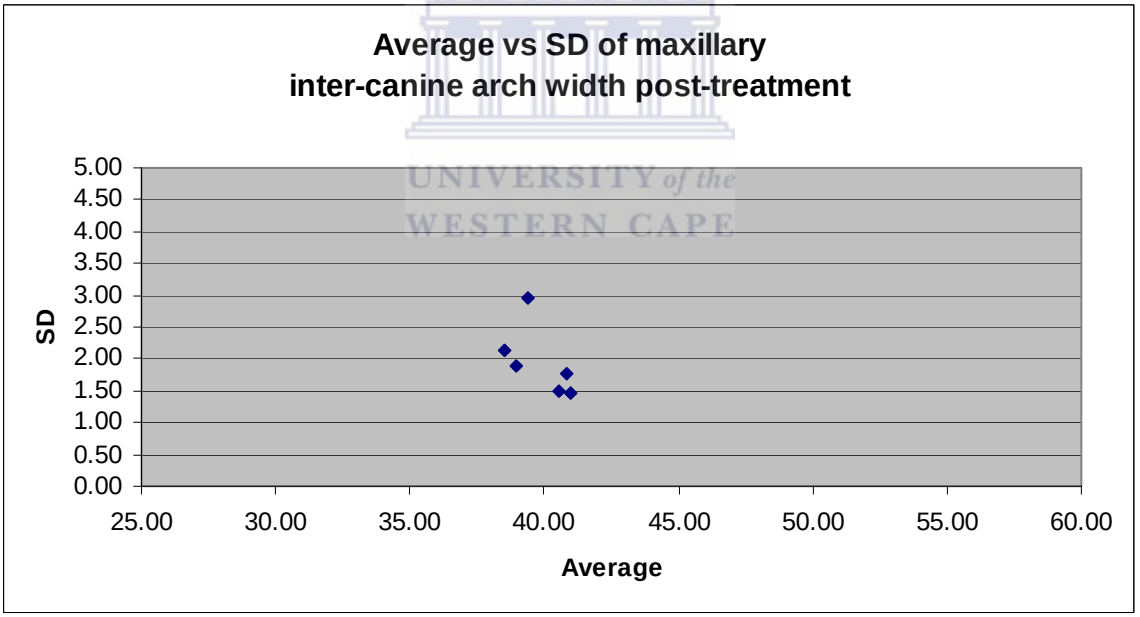

Figure 12
Average vs. the Standard Deviation of the maxillary inter-canine post-treatment arch width values.

Figures 11 and 12 show the average vs. the standard deviation for the three treatment groups, and averages for males and females for the maxillary inter-canine pre-treatment and post-treatment values from Tables 13 and 14. An increase in the average inter-canine widths post-treatment can be seen in the figures.

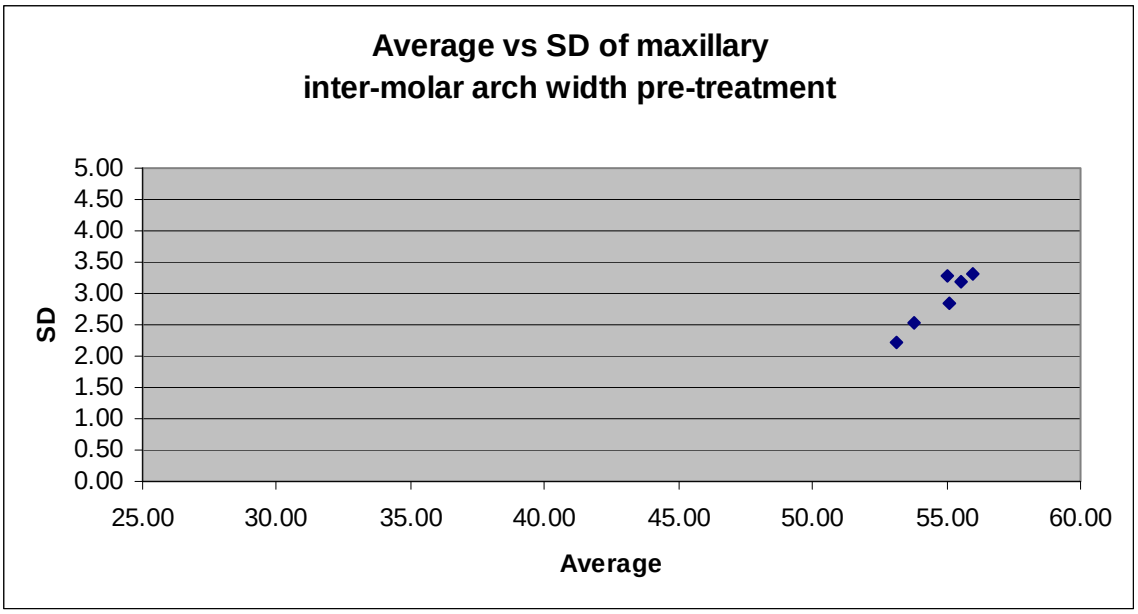

Figure 13
Average vs. the Standard Deviation of the maxillary inter-molar pre-treatment arch width values.

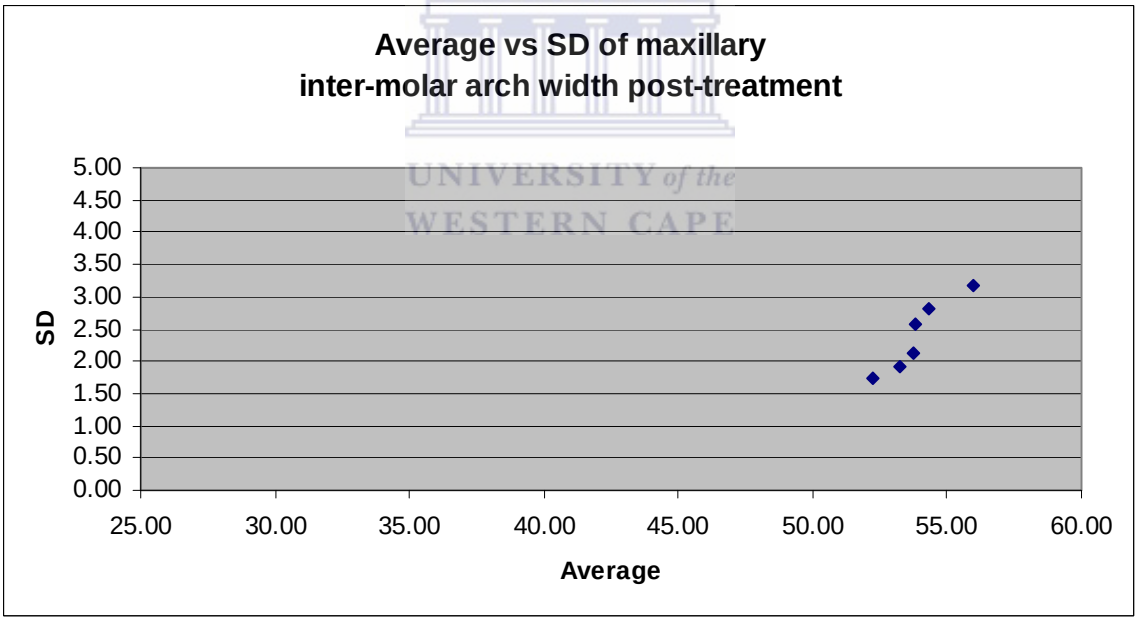

Figure 14
Average vs. the Standard Deviation of the maxillary inter-molar post-treatment arch width values.

Figures 13 and 14 show the average vs. the standard deviation for the three treatment groups, and averages for males and females for the maxillary inter-molar pre-treatment and post-treatment values from Tables 19 and 20. It is evident that there was mainly a decrease in the average inter- molar arch widths post-treatment.

4.2.3 Average change in arch widths in the mandible

The descriptive and analytical statistics for the average changes in arch widths at the inter-canine, inter-first premolar, inter-second premolar and inter-molar positions for the mandible and maxilla for the three treatment groups are presented in Tables 21-28.

Inter-canine arch width: *Table 21 and Figure 15*

Group NE had an average arch width increase of 1.11mm. For Group 44 there was an increase in average arch width of 2.07mm. In Group 45 there was in increase in average arch width of 1.5mm. All these increases were statistically significant ($p<0.05$). In Group 44 the males showed an average increase of 0.89mm more than females in arch width. The other two treatment groups showed almost similar values for both males and females. The average inter-canine arch width increase was not statistically significant between Group 44 and Group 45 ($p>0.10$).

Figure 15 shows the average changes in inter-canine arch width for the mandible for the three treatment groups: Group NE, Group 44 and Group 45. All three treatment groups showed an increase in average mandibular inter-canine arch width, with the two extraction groups, Group 44 and Group 45, showing more of an increase compared with Group NE.

Inter-first premolar arch width: *Table 22*

In group NE there was an average arch width increase of 1.55mm and group 45 showed an average increase in arch width of 2.45mm ($p<0.05$). Group NE showed almost similar values for both males and females. Group 45 showed an average increase of 0.74mm more in arch width for the males.

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Table 21

Descriptive and analytical statistics for the three treatment groups for the average change in arch width in mandibular inter-canine region.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count	13	13	13	39
	Average	1.62	1.33	0.97	1.31
	Standard Deviation	1.56	1.52	0.99	1.37
	Minimum	-0.4	-1.0	-0.5	-1.0
	Maximum	4.7	3.9	3.1	4.7
M	Count	13	13	13	39
	Average	2.51	1.68	1.24	1.81
	Standard Deviation	1.52	1.32	1.15	1.41
	Minimum	0.6	-1.1	-1.2	-1.2
	Maximum	5.8	3.8	3.5	5.8
Count of both genders		26	26	26	78
Average		2.07	1.50	1.11	1.56
Standard Deviation		1.58	1.41	1.06	1.41
Minimum		-0.4	-1.1	-1.2	-1.2
Maximum		5.8	3.9	3.5	5.8
Wilcoxon Signed rank sum test (p-value)		0.00001*	0.0002*	0.0002*	
Kruskal-Wallis test for Groups 44 and 45 (p-value)		0.3698			

* = statistically significant at the 95% level of significance

Table 22

Descriptive and analytical statistics for the two treatment groups for the average change in arch width in mandibular inter-first premolar region.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count		13	13	26
	Average		2.08	1.64	1.86
	Standard Deviation		1.72	1.57	1.63
	Minimum		-0.5	-0.5	-0.5
	Maximum		5.3	4.3	5.3
M	Count		13	13	26
	Average		2.82	1.46	2.14
	Standard Deviation		1.89	2.31	2.18
	Minimum		-0.7	-2.4	-2.4
	Maximum		5.9	7.5	7.5
Count of both genders			26	26	52
Average			2.45	1.55	2.00
Standard Deviation			1.81	1.94	1.91
Minimum			-0.7	-2.4	-2.4
Maximum			5.9	7.5	7.5
Wilcoxon Signed rank sum test (p-value)			0.0001*	0.0002*	
Kruskal-Wallis test for Groups 44 and 45 (p-value)					

* = statistically significant at the 95% level of significance

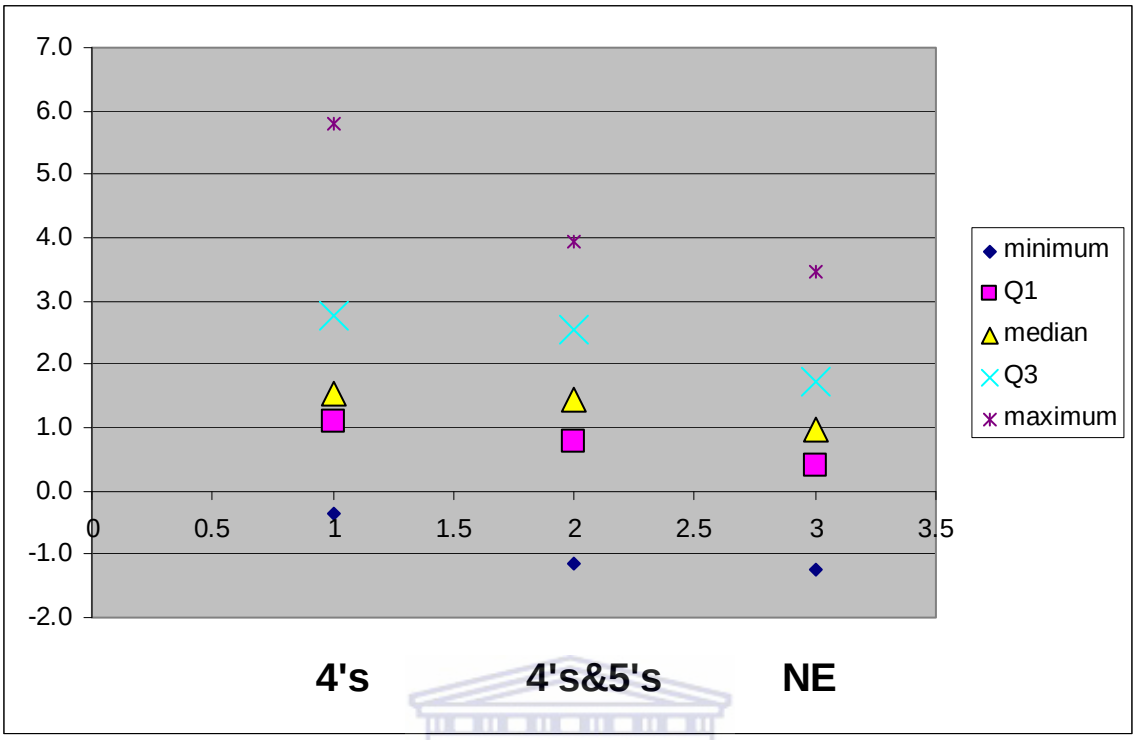

Figure 15
Average changes in arch width for the mandibular inter-canine arch width for the three treatment groups: 44, 45 and NE.

Inter-second premolar arch width: *Table 23*

Group NE had an average arch width increase of 0.93mm and in Group 44 there was a decrease in average arch width of 1.66mm ($p<0.05$). Group NE showed an average of 0.52mm more increase in arch width for the males compared with females. Group 44 showed almost similar values for both males and females.

Inter-molar arch width: *Table 24 and Figure 16*

Group NE recorded an average arch width increase of 0.19mm. For Group 44 there was a decrease in average arch width of 2.15mm. In Group 45 there was a decrease in average arch width of 2.47mm. In Group 44 and Group 45 these decreases were statistically significant ($p<0.05$). The average inter-molar arch width decrease was not statistically significant however, between Group 44 and Group 45 ($p>0.10$). All three treatment groups showed almost similar values for both males and females.

Figure 16 shows the average changes in arch width for the mandibular inter-molar region for the three treatment groups: Group NE, Group 44 and Group 45. The two extraction groups show a decrease in average arch width in the maxillary inter-molar area. Group 45 shows a greater decrease in average maxillary inter-molar arch width than did Group 44.

Table 23

Descriptive and analytical statistics for the two treatment groups for the average change in arch width in mandibular inter-second premolar region.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count	13		13	26
	Average	-1.71		0.67	-0.52
	Standard Deviation	2.16		1.41	2.16
	Minimum	-4.8		-1.4	-4.8
	Maximum	2.4		2.4	2.4
M	Count	13		13	26
	Average	-1.62		1.19	-0.21
	Standard Deviation	2.12		1.90	2.44
	Minimum	-4.8		-1.1	-4.8
	Maximum	1.7		5.7	5.7
Count of both genders		26		26	52
Average		-1.66		0.93	-0.37
Standard Deviation		2.10		1.66	2.29
Minimum		-4.8		-1.4	-4.8
Maximum		2.4		5.7	5.7
Wilcoxon Signed rank sum test (p-value)		0.0014*		0.0188*	
Kruskal-Wallis test for Groups 44 and 45 (p-value)					

* = statistically significant at the 95% level of significance

Table 24

Descriptive and analytical statistics for the three treatment groups for the average change in arch width in mandibular inter-molar region.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count	13	13	13	39
	Average	-2.14	-2.30	0.04	-1.47
	Standard Deviation	1.08	1.41	1.22	1.63
	Minimum	-4.2	-4.9	-2.1	-4.9
	Maximum	0.2	-0.3	2.5	2.5
M	Count	13	13	13	39
	Average	-2.16	-2.63	0.33	-1.49
	Standard Deviation	1.09	1.35	1.23	1.78
	Minimum	-4.4	-5.6	-1.3	-5.6
	Maximum	-0.6	-0.9	3.1	3.1
Count of both genders		26	26	26	78
Average		-2.15	-2.47	0.19	-1.48
Standard Deviation		1.06	1.36	1.21	1.69
Minimum		-4.4	-5.6	-2.1	-5.6
Maximum		0.2	-0.3	3.1	3.1
Wilcoxon Signed rank sum test (p-value)		0.0001*	0.0001*	0.501	
Kruskal-Wallis test for Groups 44 and 45 (p-value)		0.453			

* = statistically significant at the 95% level of significance

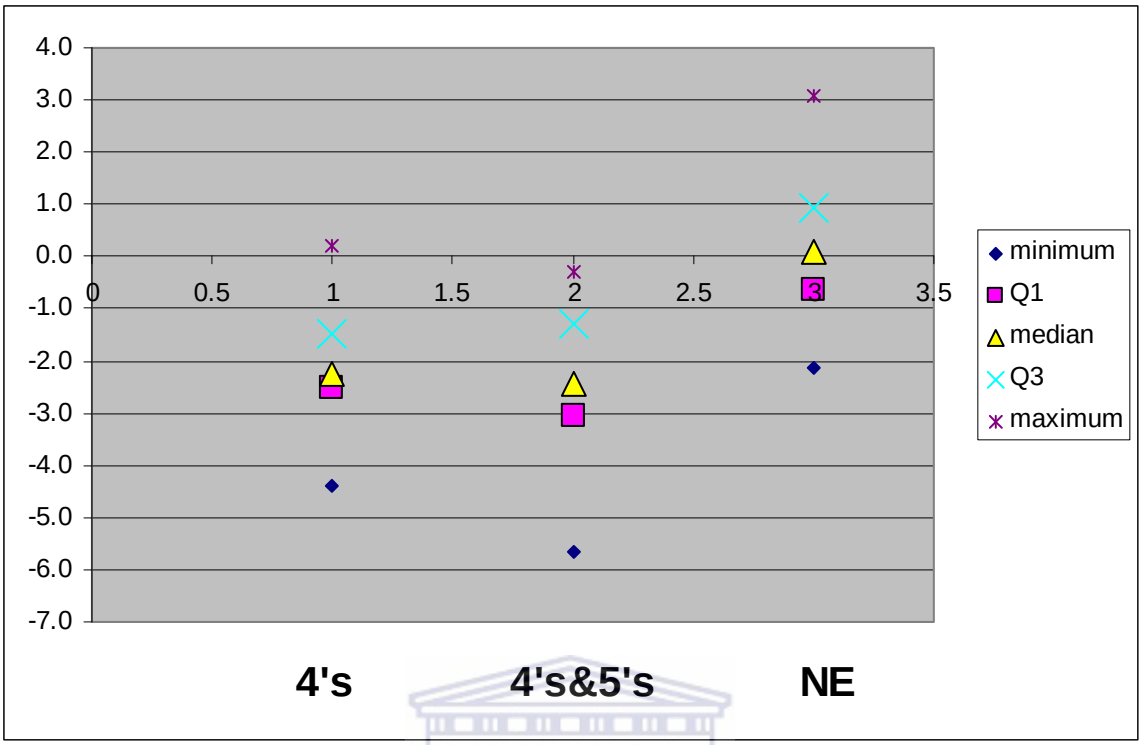

Figure 16
Average changes in arch width for the mandibular inter-molar arch width for the three treatment groups: 44, 45 and NE.

4.2.4 Average change in arch widths in the maxilla

Inter-canine arch width: *Table 25 and Figure 17*

Group NE had an average arch width increase of 1.22mm, in Group 44 there was an average increase in arch width of 1.84mm and in Group 45 there was an increase in average arch width of 2.07mm. All these increases were statistically significant ($p<0.05$). In Group NE the females had an average of about 1mm more arch width increase than the males. The males and females had almost similar values for both the extraction groups. The average inter-canine arch width increase was not significantly different between Group 44 and Group 45 ($p>0.10$).

Figure 17 shows the average changes in arch width for the maxillary inter-canine region for the three treatment groups: Group NE, Group 44 and Group 45. All three treatment groups showed an increase in average maxillary inter-canine arch width, with the two extraction groups, Group 44 and Group 45, showing more of an increase compared with Group NE.

Inter-first premolar arch width: Table 26

Group NE had an average arch width increase of 2.64mm. This increase was statistically significant ($p<0.05$). In Group NE there was an average of 0.58mm greater increase in the male group.

Table 25
Descriptive and analytical statistics for the three treatment groups for the average change in arch width in maxillary inter-canine region.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count	13	13	13	39
	Average	1.78	2.16	1.71	1.88
	Standard Deviation	1.57	1.64	1.62	1.58
	Minimum	-1.2	-1.1	-1.0	-1.2
	Maximum	4.8	5.0	3.5	5.0
M	Count	13	13	13	39
	Average	1.90	1.98	0.72	1.54
	Standard Deviation	1.84	1.97	3.23	2.43
	Minimum	-1.3	-1.7	-9.1	-9.1
	Maximum	6.1	4.2	3.7	6.1
Count of both genders		26	26	26	78
Average		1.84	2.07	1.22	1.71
Standard Deviation		1.68	1.78	2.55	2.05
Minimum		-1.3	-1.7	-9.1	-9.1
Maximum		6.1	5.0	3.7	6.1
Wilcoxon Signed rank sum test (p-value)		0.0001*	0.0002*	0.001*	
Kruskal-Wallis test for Groups 44 and 45 (p-value)		0.3897			

* = statistically significant at the 95% level of significance

Table 26
Descriptive and analytical statistics for the NE treatment group for the average change in arch width in maxillary inter-first premolar region.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count			13	13
	Average			2.35	2.35
	Standard Deviation			2.01	2.01
	Minimum			-1.3	-1.3
	Maximum			5.1	5.1
M	Count			13	13
	Average			2.93	2.93
	Standard Deviation			1.36	1.36
	Minimum			0.9	0.9
	Maximum			4.9	4.9
Count of both genders				26	26
Average				2.64	2.64
Standard Deviation				1.71	1.71
Minimum				-1.3	-1.3
Maximum				5.1	5.1
Wilcoxon Signed rank sum test (p-value)				0.0001*	
Kruskal-Wallis test for Groups 44 and 45 (p-value)					

* = statistically significant at the 95% level of significance

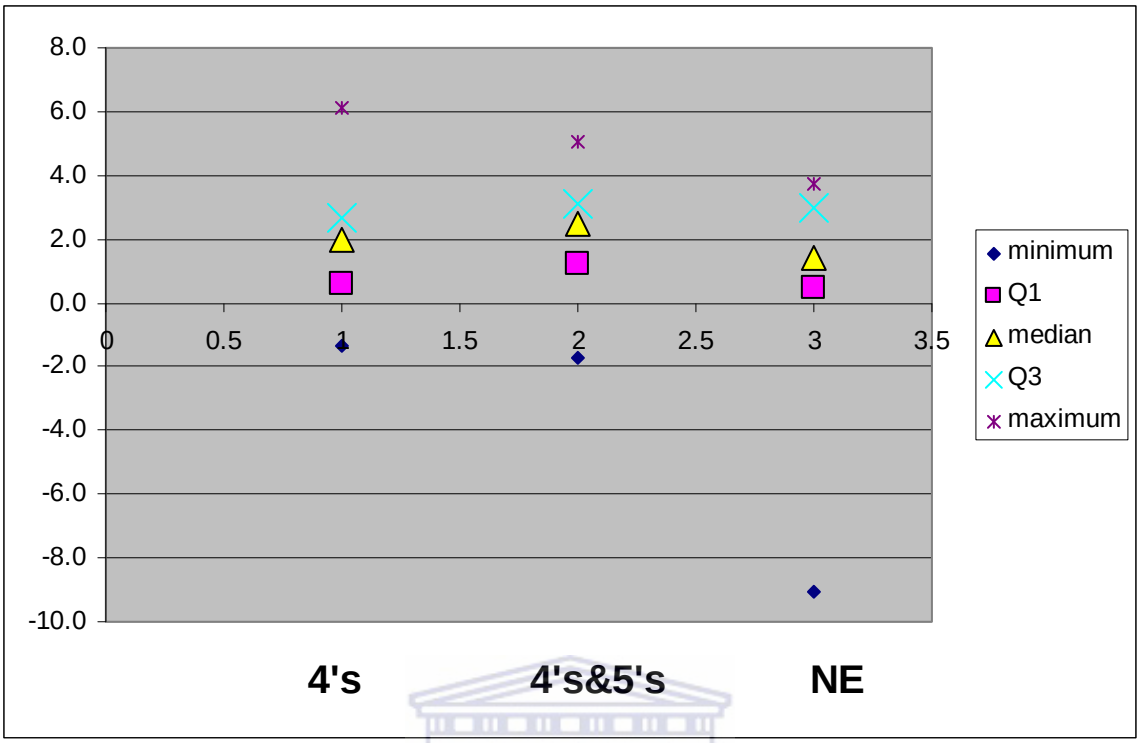

Figure 17
Average changes in arch width for the maxillary inter-canine arch width for the three treatment groups: 44, 45 and NE.

Inter-second premolar arch width: *Table 27*

Group NE had an average arch width increase of 2.1mm. For Group 44 there was a decrease in average arch width of 1.01mm. In Group 45 there was a decrease in average arch width of 0.29mm. For Group NE and Group 44 these changes were statistically significant ($p<0.05$). The average inter-second premolar arch width decrease was not statistically significant between Group 44 and Group 45 ($p>0.10$). All three treatment groups showed almost similar values for both males and females.

Inter-molar arch width: *Table 28 and Figure 18*

Group NE had an average arch width increase of 0.23mm. For Group 44 there was a decrease in average arch width of 1.79mm. In Group 45 there was a decrease in arch width of 1.09mm. For Group 44 and Group 45 these decreases were statistically significant ($p<0.05$). For the maxillary inter-molar arch width, Group 44 showed a significant more decrease in arch width compared with Group 45. The average inter-molar arch width decrease was statistically significant between Group 44 and Group 45 at the 90% level of significance ($p<0.10$). All three treatment groups showed almost similar values for both males and females.

Figure 18 shows the average changes in arch width for the maxillary inter-molar region for the 3 treatment groups: Group NE, Group 44 and Group 45. The two extraction groups showed a decrease in average arch width in the maxillary inter-molar area. Group 44 shows a greater decrease in average maxillary inter-molar arch width than Group 45.

Table 27

Descriptive and analytical statistics for the three treatment groups for the average change in arch width in maxillary inter-second premolar region.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count	13	13	13	39
	Average	-0.78	-0.26	2.10	0.35
	Standard Deviation	2.66	1.85	1.85	2.45
	Minimum	-4.5	-3.7	-1.3	-4.5
	Maximum	4.5	2.4	5.1	5.1
M	Count	13	13	13	39
	Average	-1.24	-0.31	2.09	0.18
	Standard Deviation	1.85	3.23	1.40	2.65
	Minimum	-4.6	-6.2	0.1	-6.2
	Maximum	1.3	6.7	5.3	6.7
Count of both genders		26	26	26	78
Average		-1.01	-0.29	2.10	0.27
Standard Deviation		2.26	2.58	1.61	2.54
Minimum		-4.6	-6.2	-1.3	-6.2
Maximum		4.5	6.7	5.3	6.7
Wilcoxon Signed rank sum test (p-value)		0.049*	0.5338	0.0001*	
Kruskal-Wallis test for Groups 44 and 45 (p-value)		0.2342			

* = statistically significant at the 95% level of significance

Table 28

Descriptive and analytical statistics for the three treatment groups for the average change in arch width in maxillary intermolar region.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count	13	13	13	39
	Average	-1.70	-0.93	0.06	-0.86
	Standard Deviation	1.91	1.22	1.02	1.58
	Minimum	-4.6	-3.6	-1.4	-4.6
	Maximum	2.8	0.9	2.7	2.8
M	Count	13	13	13	39
	Average	-1.87	-1.24	0.39	-0.91
	Standard Deviation	1.21	1.93	1.25	1.75
	Minimum	-3.8	-4.6	-1.3	-4.6
	Maximum	-0.1	2.1	2.5	2.5
Count of both genders		26	26	26	78
Average		-1.79	-1.09	0.23	-0.88
Standard Deviation		1.57	1.59	1.13	1.66
Minimum		-4.6	-4.6	-1.4	-4.6
Maximum		2.8	2.1	2.7	2.8
Wilcoxon Signed rank sum test (p-value)		0.0001*	0.0042*	0.9898	
Kruskal-Wallis test for Groups 44 and 45 (p-value)		0.0594**			

* = statistically significant at the 95% level of significance

** = statistically significant at the 90% level of significance

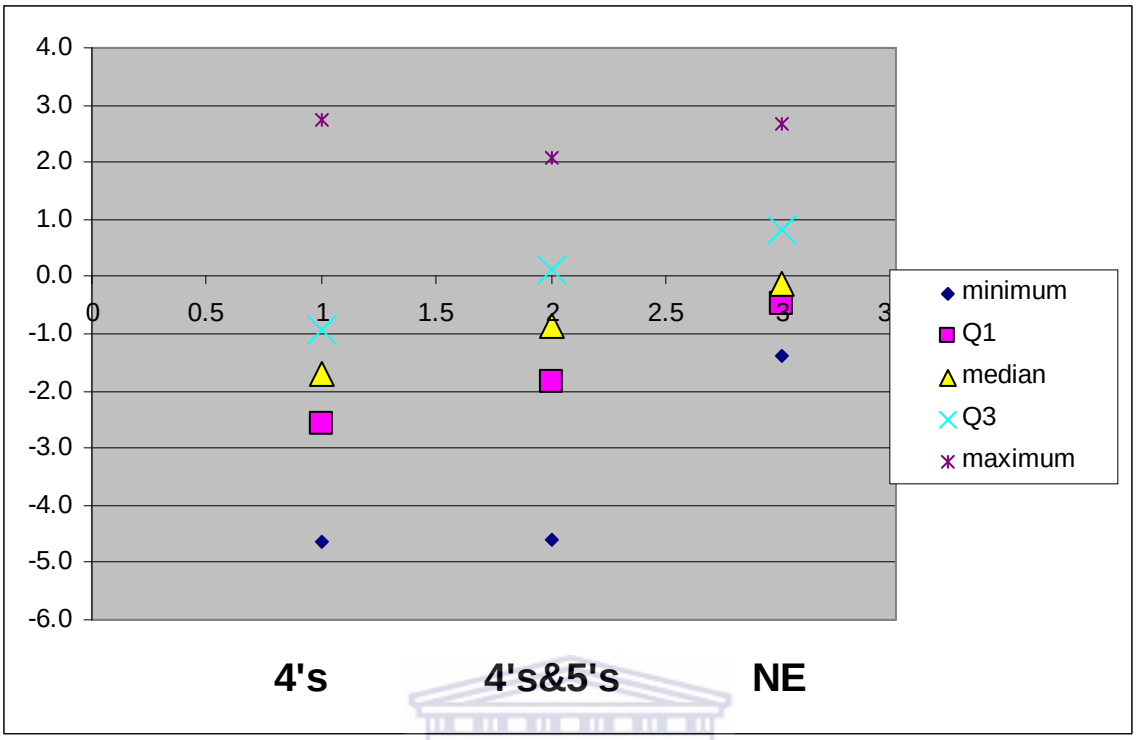

Figure 18
Average changes in arch width for the maxillary inter-molar arch width for the three treatment groups: 44, 45 and NE.

4.3 Arch length

The descriptive statistics for the pre- and post-treatment values of the average arch lengths for the mandible and maxilla are presented in Tables 29 to 32.

4.3.1 Pre-treatment study model comparison of arch length

The male samples had a longer average arch length pre-treatment compared with the female samples for all three treatment groups.

4.3.1.1 Mandibular arch length: *Table 29*

The female samples of the two extraction groups showed similar values for the average arch length pre-treatment. Group NE had a shorter average arch length of +/- 1.30mm compared with the two extraction groups in the female samples. In the male samples, Group NE and Group 44 had similar values. In Group 45 the average arch length was +/- 2.9mm larger for the male sample.

For the combined averages Group 45 had the largest average arch length, with Group 44 showing an average of 1.38mm shorter and Group NE an average of 2.18mm shorter compared with the Group 45.

4.3.1.2 Maxillary arch length: *Table 31*

In the female sample Group 44 had the largest average arch length, with Group NE an average of 3.04mm shorter and Group 45 an average of 4.36mm shorter. The male samples of Group NE and Group 45 had similar values. Group 44 had a longer average arch length of +/-2.25mm in the male sample compared with the other two groups.

For the combined averages group 44 had the largest average arch length, with Group NE an average of 2.64mm shorter and Group 45 an average of 3.41mm shorter in arch length compared with the first group.

4.3.2 Post-treatment study model comparison of arch length

In Group NE and Group 45 the males had longer average arch lengths than females post-treatment. Group 44 had almost similar values for the males and females.

4.3.2.1 Mandibular arch length: *Table 30*

The female group had a longer average arch length in Group 44 and the males had a longer average arch length in Group 45. Group NE had a longer average arch length in the male sample. For the two extraction groups the combined averages had almost similar values.

4.3.2.2 Maxillary arch length: *Table 32*

Of the two extraction groups, Group 45 had the shortest average arch length in both the female and male groups. In Group 44 the male and female samples had almost similar values whereas the male group had a larger average arch length in Group 45. In Group NE the males had a longer average arch length. Group 45 had the shortest average in the combined averages.

Table 29
Descriptive statistics for the three treatment groups for the mandibular pre-treatment arch length measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	60.79	60.64	59.30	60.24
	Standard Deviation	3.36	4.38	3.43	3.71
	Minimum	54.64	54.32	53.50	53.50
	Maximum	65.59	72.41	66.70	72.41
M	Count	13	13	13	39
	Average	61.40	64.30	61.28	62.33
	Standard Deviation	4.24	4.25	4.99	4.61
	Minimum	54.94	58.70	54.68	54.68
	Maximum	68.63	72.87	69.95	72.87
Count of both genders		26	26	26	78
Average		61.09	62.47	60.29	61.29
Standard Deviation		3.76	4.63	4.31	4.29
Minimum		54.64	54.32	53.50	53.50
Maximum		68.63	72.87	69.95	72.87

Table 30
Descriptive statistics for the three treatment groups for the mandibular post-treatment arch length measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	51.59	50.34	60.58	54.17
	Standard Deviation	2.11	4.28	2.53	5.53
	Minimum	47.83	46.23	55.30	46.23
	Maximum	55.94	63.42	63.87	63.87
M	Count	13	13	13	39
	Average	51.33	52.73	63.98	56.01
	Standard Deviation	2.79	3.23	3.87	6.59
	Minimum	47.76	48.27	59.63	47.76
	Maximum	55.52	58.61	71.37	71.37
Count of both genders		26	26	26	78
Average		51.46	51.54	62.28	55.09
Standard Deviation		2.43	3.91	3.64	6.11
Minimum		47.76	46.23	55.30	46.23
Maximum		55.94	63.42	71.37	71.37

Table 31
Descriptive statistics for the three treatment groups for the maxillary pre-treatment arch length measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	72.99	68.63	69.95	70.52
	Standard Deviation	2.63	5.67	3.97	4.55
	Minimum	68.73	57.57	63.04	57.57
	Maximum	78.28	79.24	75.86	79.24
M	Count	13	13	13	39
	Average	74.15	71.69	71.90	72.58
	Standard Deviation	5.17	7.40	5.15	5.95
	Minimum	63.53	55.90	62.88	55.90
	Maximum	83.41	83.36	79.19	83.41
Count of both genders		26	26	26	78
Average		73.57	70.16	70.93	71.55
Standard Deviation		4.06	6.65	4.62	5.36
Minimum		63.53	55.90	62.88	55.90
Maximum		83.41	83.36	79.19	83.41

Table 32
Descriptive statistics for the three treatment groups for the maxillary post-treatment arch length measurement.

		Group 44	Group 45	Group NE	Total
Gender	Data				
F	Count	13	13	13	39
	Average	61.46	56.89	68.86	62.41
	Standard Deviation	2.42	3.14	3.89	5.89
	Minimum	57.24	49.24	61.03	49.24
	Maximum	65.91	60.86	76.12	76.12
M	Count	13	13	13	39
	Average	61.53	58.61	72.90	64.34
	Standard Deviation	3.51	6.70	4.31	7.93
	Minimum	57.20	41.33	65.90	41.33
	Maximum	68.68	66.26	79.55	79.55
Count of both genders		26	26	26	78
Average		61.50	57.75	70.88	63.37
Standard Deviation		2.95	5.20	4.52	7.01
Minimum		57.20	41.33	61.03	41.33
Maximum		68.68	66.26	79.55	79.55

4.3.3 Pre- and Post-treatment Average vs. Standard Deviation of the three treatment groups for arch length in the mandibular and maxillary arches

Figures 19, 20, 21 and 22 plots the average against the standard deviation (SD) for the three groups of treatment based on the averages for males and females of the arch length of the mandible and maxilla, pre- and post-treatment, from Tables 29, 30, 31 and 32. Post-treatment Group NE showed an increase in mandibular average arch length and almost unchanged maxillary average arch length. For Group 44 and Group 45 the average arch length decreased in both the mandible and maxilla.

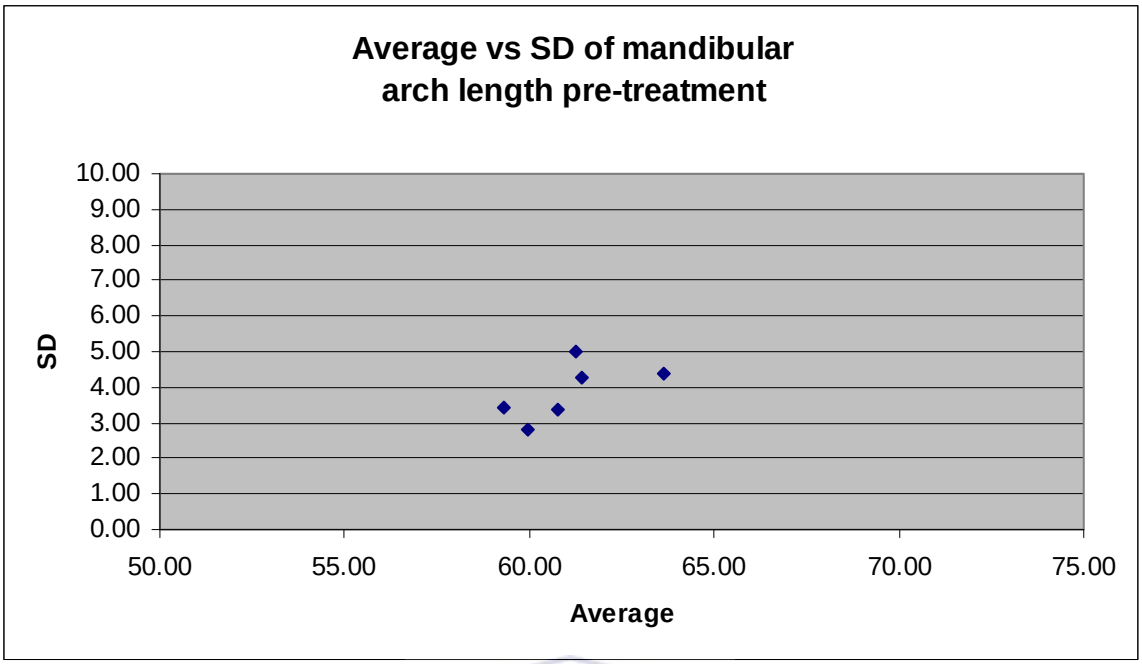

Figure 19
Average vs. the Standard Deviation of the mandibular arch length pre-treatment.

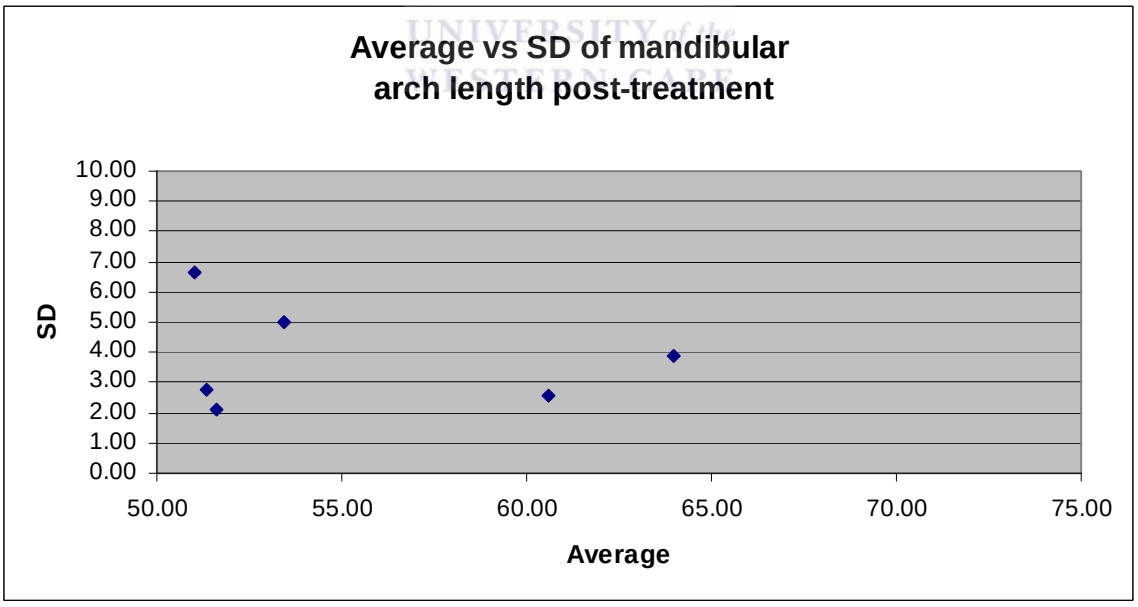

Figure 20
Average vs. the Standard Deviation of the mandibular arch length post-treatment.

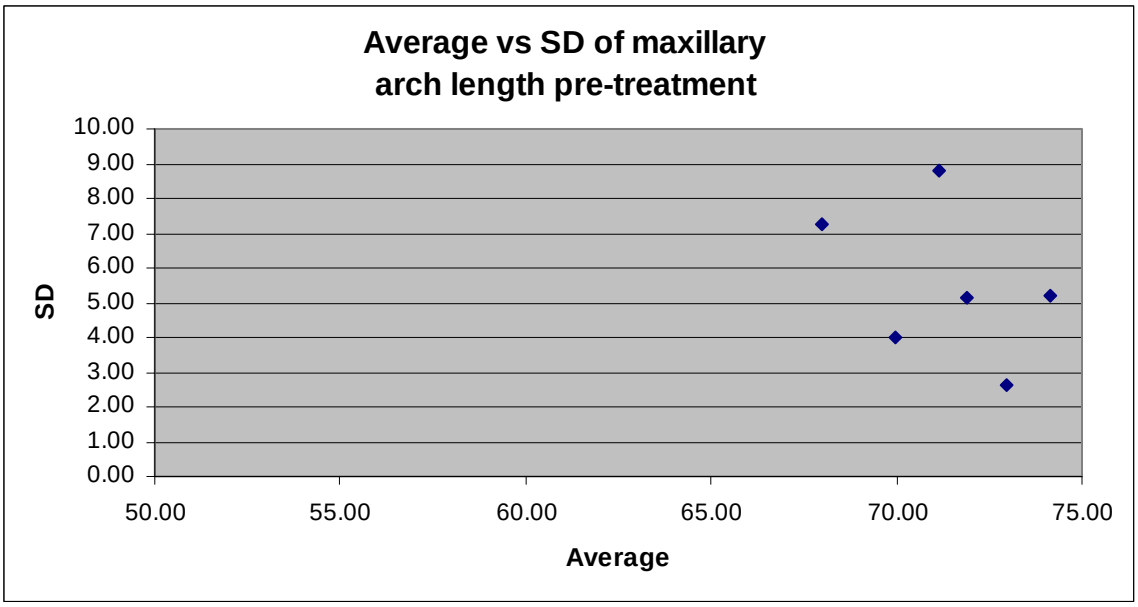

Figure 21
Average vs. the Standard Deviation of the maxillary arch length pre-treatment.

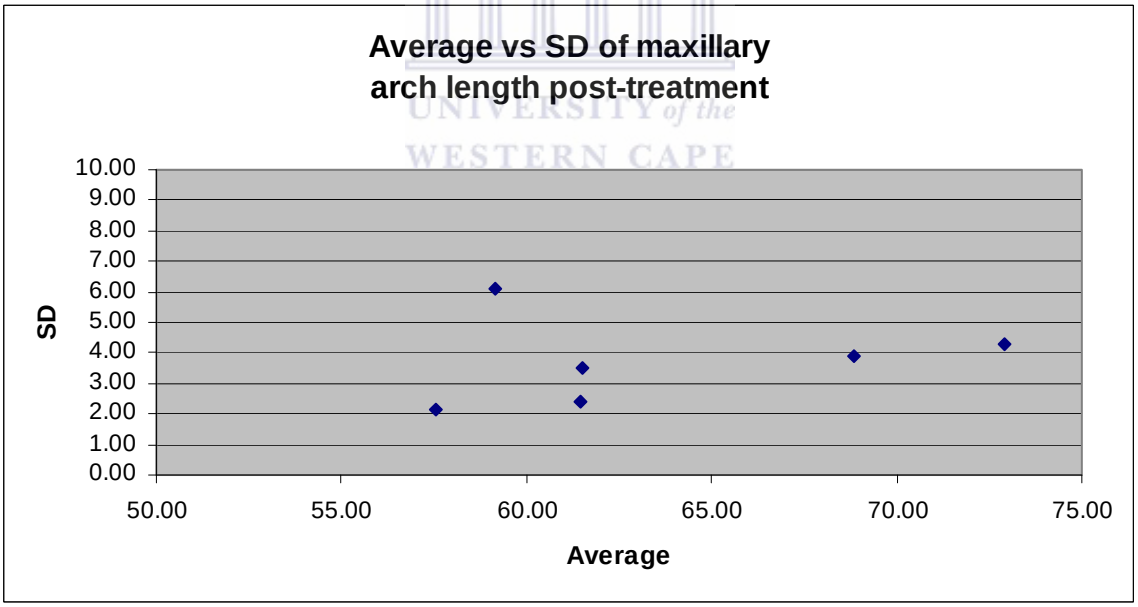

Figure 22
Average vs. the Standard Deviation of the maxillary arch length post-treatment.

4.3.4 Average change in arch length

The descriptive and analytical statistics for the average change in arch length for the mandible and maxilla for the three treatment groups are presented in Tables 33 and 34.

4.3.4.1 Mandible: *Table 33*

Group NE had an average arch length increase of 1.99mm. For Group 44 there was a decrease in average arch length of 9.64mm and in Group 45 there was a decrease in average arch length of 10.93mm. The increase in Group NE and decreases in Group 44 and Group 45 were statistically significant ($p<0.05$). For Group NE there was a greater average arch length increase in the males, compared with the females. In the two extraction groups the males had greater average arch length decreases than the females. The average mandibular arch length decrease was not statistically significant between Group 44 and Group 45 ($p>0.05$).

4.3.4.2 Maxilla: *Table 34*

Group NE had an average arch length decrease of 0.05mm. For Group 44 there was a decrease in average arch length of 12.07mm. In Group 45 there was a decrease in average arch length of 12.41mm. The decreases in Group 44 and Group 45 were statistically significant ($p<0.05$). For Group NE the males and females showed almost similar values. The two extraction groups showed a greater average arch length decrease for the males compared with the females. The average maxillary arch length decrease was not significantly different between Group 44 and Group 45 ($p>0.05$).

Table 33
Descriptive and analytical statistics for the three treatment groups for the average change in mandibular arch length measurement.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count	13	13	13	39
	Average	-9.21	-10.30	1.27	-6.08
	Standard Deviation	3.22	2.22	1.83	5.82
	Minimum	-13.7	-14.5	-3.5	-14.5
	Maximum	-4.0	-8.0	4.0	4.0
M	Count	13	13	13	39
	Average	-10.07	-11.57	2.70	-6.31
	Standard Deviation	2.74	3.85	3.19	7.23
	Minimum	-14.8	-17.7	-1.2	-17.7
	Maximum	-6.1	-6.2	11.3	11.3
Count of both genders		26	26	26	78
Average		-9.64	-10.93	1.99	-6.19
Standard Deviation		2.96	3.15	2.65	6.52
Minimum		-14.8	-17.7	-3.5	-17.7
Maximum		-4.0	-6.2	11.3	11.3
Wilcoxon Signed rank sum test (p-value)		0.0001*	0.0001*	0.0002*	
Kruskal-Wallis test for Groups 44 and 45 (p-value)		0.1699			

- = statistically significant at the 95% level of significance

Table 34
Descriptive and analytical statistics for the three treatment groups for the average change in maxillary arch length measurement.

		Group	Group	Group	
Gender	Data	44	45	NE	Total
F	Count	13	13	13	39
	Average	-11.52	-11.74	-1.09	-8.12
	Standard Deviation	3.79	4.04	2.42	6.08
	Minimum	-16.6	-20.3	-4.1	-20.3
	Maximum	-4.9	-4.6	2.7	2.7
M	Count	13	13	13	39
	Average	-12.62	-13.08	1.00	-8.23
	Standard Deviation	3.09	8.58	4.37	8.72
	Minimum	-18.8	-37.2	-5.5	-37.2
	Maximum	-6.3	-4.3	10.0	10.0
Count of both genders		26	26	26	78
Average		-12.07	-12.41	-0.05	-8.18
Standard Deviation		3.44	6.61	3.62	7.47
Minimum		-18.8	-37.2	-5.5	-37.2
Maximum		-4.9	-4.3	10.0	10.0
Wilcoxon Signed rank sum test (p-value)		0.0001*	0.0001*	0.6568	
Kruskal-Wallis test for Groups 44 and 45 (p-value)		0.4754			

* = statistically significant at the 95% level of significance

4.4 Summary of average change in the arch widths and lengths of the three treatment groups for the mandible and maxilla

Table 35
Summary of average change in arch width in mandible for the three treatment groups: inter-canine, inter-first premolar, inter-second premolar and inter-molar.

	Group 44	Group 45	Group NE
Treatment effect inter-canine	2.07*	1.50*	1.11*
Treatment effect inter-first premolar		2.45*	1.55*
Treatment effect inter-second premolar	-1.66*		0.93*
Treatment effect inter-molar	-2.15*	-2.47*	0.19

* = statistically significant at the 95% level of significance

Group NE shows an increase in the inter-canine, inter-first premolar, inter-second premolar and inter-molar arch widths. The two extraction groups show an increase in inter-canine arch width and a decrease in inter-molar arch widths. In Group 45 the inter-first premolar arch width increased and in Group 44 the inter-second premolar arch width decreased.

Table 36
Summary of average change in arch width in maxilla for the three treatment groups: inter-canine, inter-first premolar, inter-second premolar and inter-molar.

	Group 44	Group 45	Group NE
Treatment effect inter-canine	1.84*	2.07*	1.22*
Treatment effect inter-first premolar			2.64*
Treatment effect inter-second premolar	-1.01*	-0.29	2.10*
Treatment effect inter-molar	-1.79*	-1.09*	0.23

- = statistically significant at the 95% level of significance

Group NE shows an increase in the inter-canine, inter-first premolar, inter-second premolar and inter-molar arch widths. The two extraction groups show an increase in inter-canine arch width, decrease in inter-second premolar arch width and a decrease in inter-molar arch widths.

Table 37
Summary of average change in arch length for the three treatment groups: Mandible and Maxilla.

	Group 44	Group 45	Group NE
Average change in Arch length Mandible	-9.64*	-10.93*	1.99*
Average change in Arch length Maxilla	-12.07*	-12.41*	-0.05

* = statistically significant at the 95% level of significance

Group NE show an increase in mandibular arch length and the maxillary arch length essentially unchanged. Both extraction groups show a decrease in arch length for both the mandible and maxilla.

4.5 Comparisons of the 3 study groups tested for level of significance.

Table 38 shows the Kruskal-Wallis test values for the different average arch width measurements as well as the average arch length measurements in the three treatment groups. The three groups of treatment were compared with each other, to determine whether the treatment was statistically significant or not for the arch width and arch length measurements. Significant effect is indicated with a p-value less than 0.05.

Table 38: Kruskal-Wallis test values for comparison of the age at start of treatment, treatment period, arch width and arch length: H-Stat, p-value and Chi-squared Critical.

	H-Stat	p-value	Chi-squared Critical
Average age at start of treatment	5.7044	0.0577	5.9915
Average treatment period	5.7449	0.0566	5.9915
Average change in mandibular inter-canine arch width	4.5898	0.1008	5.9915
Average change in mandibular inter-first premolar arch width	3.8706	0.0491	3.8415
Average change in mandibular inter-second premolar arch width	15.6267	0.0001	3.8415
Average change in mandibular inter-molar arch width	41.1353	0.0001	5.9915
Average change in maxillary inter-canine arch width	1.6513	0.438	5.9915
Average change in maxillary inter-first premolar arch width	No data	No data	No data
Average change in maxillary inter-second premolar arch width	25.7677	0.0001	5.9915
Average change in maxillary inter-molar arch width	23.4288	0.0001	5.9915
Average change in mandibular arch length	52.1844	0.0001	5.9915
Average change in maxillary arch length	50.9638	0.0001	5.9915

The mandibular inter-first and inter-second premolar arch widths showed p-values less than 0.05 which indicate a statistically significant effect in the change in arch width in these areas. The other areas of note for statistical significance were the mandibular inter-molar, maxillary inter-second premolar and maxillary inter-molar width measurements,

which show a very small p-value of 0.0001. For the arch length data both the mandibular and maxillary p-values are 0.0001, indicating highly significant differences.

For the average age at start of treatment and average treatment period the p-values were just more than 0.05, reflecting a comparison between the means.

4.6 Correlation analyses

4.6.1 Correlation analyses of non-extraction group (Group NE): Table 39

In Group NE there was a strong correlation between the arch width changes in the mandibular inter-first premolar area and the arch width changes in the mandibular inter-canine area. Changes in the arch width in the mandibular inter-second premolar area and the mandibular inter-first premolar area were also strongly correlated. In the maxillary arch the changes in the arch width of the maxillary inter-second premolar and maxillary inter-first premolar areas showed strong correlation. The changes in the arch length in the maxilla were strongly correlated with the changes in the arch length in the mandible. The correlation coefficient values were all above 0.6.

4.6.2 Correlation analyses of upper and lower first premolar extraction group (Group 44): Table 40

In Group 44 the arch width changes of the maxillary inter-canine area were strongly correlated with the changes in arch width of the mandibular inter-canine area. The arch width changes of the maxillary inter-second premolar showed strong correlation with the arch width changes of the mandibular inter-second premolar area. All had correlation coefficient values above 0.6.

4.6.3 Correlation analyses of upper first and lower second premolar extraction group (Group 45): Table 41

In Group 45 there was strong correlation between the arch width changes in the maxillary inter-second premolar and mandibular inter-canine area. The arch width changes of the maxillary inter-second premolar also showed strong correlation with the arch width changes in the mandibular inter-first premolar area. The arch width changes in the maxillary inter-molar area showed strong correlation with the arch width changes in the mandibular inter-molar area. The arch width changes of the maxillary inter-molar area

also showed strong correlation with the arch width changes in the maxillary inter-second premolar area. The changes in the arch length in the maxilla showed strong correlation with the changes in the arch length in the mandible. All these comparisons had correlation coefficient values above 0.6.

Table 39
Correlation analyses of the non-extraction group (Group NE).

	AgeAt Start of treatment	Treat Period	Average Change in arch width Inter-canine Man	Average Change in arch width first Prem Man	Average Change in arch width second Prem Man	Average Change in arch width Inter-molar Man	Average Change in arch width Inter-canine Max	Average Change in arch width first Prem Max	Average Change in arch width second Prem Max	Average Change in arch width Inter-molar Max	Average Change in Arch length Man	Average Change in Arch length Max
AgeAt Start of treatment	1	0.059	-0.001	-0.123	-0.136	-0.226	0.034	-0.012	0.000	-0.299	-0.055	-0.003
Treat Period	0.059	1	0.405	0.506	0.514	0.267	-0.014	0.195	0.344	0.264	0.547	0.472
Average change in arch width Inter-canine Man	-0.001	0.405	1	0.623	0.475	0.571	0.174	0.169	0.130	0.166	0.296	0.293
Average change in arch width first Prem Man	-0.123	0.506	0.623	1	0.646	0.546	0.326	0.411	0.475	0.235	0.529	0.259
Average change in arch width second Prem Man	-0.136	0.514	0.475	0.646	1	0.585	0.024	0.195	0.270	0.090	0.520	0.216
Average change in arch width Inter-molar Man	-0.226	0.267	0.571	0.546	0.585	1	0.192	-0.079	-0.085	0.056	0.423	0.104
Average change in arch width Inter-canine Max	0.034	-0.014	0.174	0.326	0.024	0.192	1	0.406	0.295	0.258	0.055	-0.252
Average change in arch width first Prem Max	-0.012	0.195	0.169	0.411	0.195	-0.079	0.406	1	0.879	0.424	0.302	0.239
Average change in arch width second Prem Max	0.000	0.344	0.130	0.475	0.270	-0.085	0.295	0.879	1	0.408	0.441	0.395
Average change in arch width Inter-molar Max	-0.299	0.264	0.166	0.235	0.090	0.056	0.258	0.424	0.408	1	0.287	0.463
Average change in Arch length Man	-0.055	0.547	0.296	0.529	0.520	0.423	0.055	0.302	0.441	0.287	1	0.680
Average change in Arch length Max	-0.003	0.472	0.293	0.259	0.216	0.104	-0.252	0.239	0.395	0.463	0.680	1

Highlighted values indicate strong correlation.

Table 40
Correlation analyses of upper and lower first premolar extraction group (Group 44).

	AgeAt Start of treatment	Treat Period	Average Change in arch width Inter-canine Man	Average Change in arch width first Prem Man	Average Change in arch width second Prem Man	Average Change in arch width Inter-molar Man	Average Change in arch width Inter-canine Max	Average Change in arch width first Prem Max	Average Change in arch width second Prem Max	Average Change in arch width Inter-molar Max	Average Change in Arch length Man	Average Change in Arch length Max
AgeAt Start of treatment	1	-0.142	-0.118		-0.131	0.081	-0.087		-0.072	-0.036	-0.226	-0.042
Treat Period	-0.142	1	0.356		0.071	-0.057	-0.033		-0.038	-0.001	-0.250	-0.440
Average change in arch width Inter-canine Man	-0.118	0.356	1		0.296	0.103	0.624		0.146	0.257	0.095	-0.208
Average change in arch width first Prem Man				1								
Average change in arch width second Prem Man	-0.131	0.071	0.296		1	0.471	0.307		0.663	0.449	0.436	0.073
Average change in arch width Inter-molar Man	0.081	-0.057	0.103		0.471	1	0.436		0.229	0.465	0.290	-0.044
Average change in arch width Inter-canine Max	-0.087	-0.033	0.624		0.307	0.436	1		0.190	0.241	0.531	0.056
Average change in arch width first Prem Max								1				
Average change in arch width second Prem Max	-0.072	-0.038	0.146		0.663	0.229	0.190		1	0.553	0.542	0.233
Average change in arch width Inter-molar Max	-0.036	-0.001	0.257		0.449	0.465	0.241		0.553	1	0.391	0.184
Average change in Arch length Man	-0.226	-0.250	0.095		0.436	0.290	0.531		0.542	0.391	1	0.457
Average change in Arch length Max	-0.042	-0.440	-0.208		0.073	-0.044	0.056		0.233	0.184	0.457	1

Highlighted values indicate strong correlation.

Table 41
Correlation analyses of upper first and lower second premolar extraction group(Group45)

	Age At Start of treatment	Treat Period	Average Change in arch width Inter-canine Man	Average Change in arch width first Prem Man	Average Change in arch width second Prem Man	Average Change in arch width Inter-molar Man	Average Change in arch width Inter-canine Max	Average Change in arch width first Prem Max	Average Change in arch width second Prem Max	Average Change in arch width Inter-molar Max	Average Change in Arch length Man	Average Change in Arch length Max
AgeAt Start of treatment	1	-0.296	-0.256	-0.291		0.363	-0.231		-0.173	0.017	0.272	0.183
Treat Period	-0.296	1	-0.018	-0.038		-0.166	0.223		0.029	0.169	-0.348	-0.502
Average change in arch width Inter-canineMan	-0.256	-0.018	1	0.363		0.316	0.038		0.604	0.287	0.274	0.307
Average change in arch width firstPrem Man	-0.291	-0.038	0.363	1		0.232	-0.257		0.618	0.275	0.026	0.303
Average change in arch width second Prem Man					1							
Average change in arch width Inter-molar Man	0.363	-0.166	0.316	0.232		1	-0.313		0.431	0.611	0.550	0.282
Average change in arch width Inter-canineMax	-0.231	0.223	0.038	-0.257		-0.313	1		-0.223	-0.093	-0.148	-0.315
Average change in arch width first Prem Max								1				
Average change in arch width second Prem Max	-0.173	0.029	0.604	0.618		0.431	-0.223		1	0.665	0.278	0.428
Average change in arch width Inter-molar Max	0.017	0.169	0.287	0.275		0.611	-0.093		0.665	1	0.045	-0.030
Average change in Arch length Man	0.272	-0.348	0.274	0.026		0.550	-0.148		0.278	0.045	1	0.637
Average change in Arch length Max	0.183	-0.502	0.307	0.303		0.282	-0.315		0.428	-0.030	0.637	1

Highlighted values indicate strong correlation.

Figures 23, 24 and 25 show the average change in arch width for the inter-canine arch width vs. the average change in arch width for the inter-molar arch width for the three treatment groups in the mandibular arch. Figures 26, 27 and 28 show average change in arch width for the inter-canine arch width vs. the average change in arch width for the inter-molar arch width for the three treatment groups in the maxillary arch. There is a positive correlation between the average changes in arch width of the inter-canine and inter-molar areas. The positive correlation can be seen in all three groups; Group NE, Group 44 and Group 45, and also in both the mandible and maxilla. In Group NE in the mandible and maxilla the values are mostly positive for both the average inter-canine and inter-molar arch width. In both the extraction groups for both the mandible and maxilla the average inter-canine arch width values are mostly positive and the average inter-molar arch width values are mostly negative. The positive correlation might be the result of the average inter-canine arch width increasing for all three treatment groups in both the mandible and maxilla, and the average inter-molar arch width showing a decrease for both extraction groups and only a slight increase in group NE in both the mandible and maxilla.

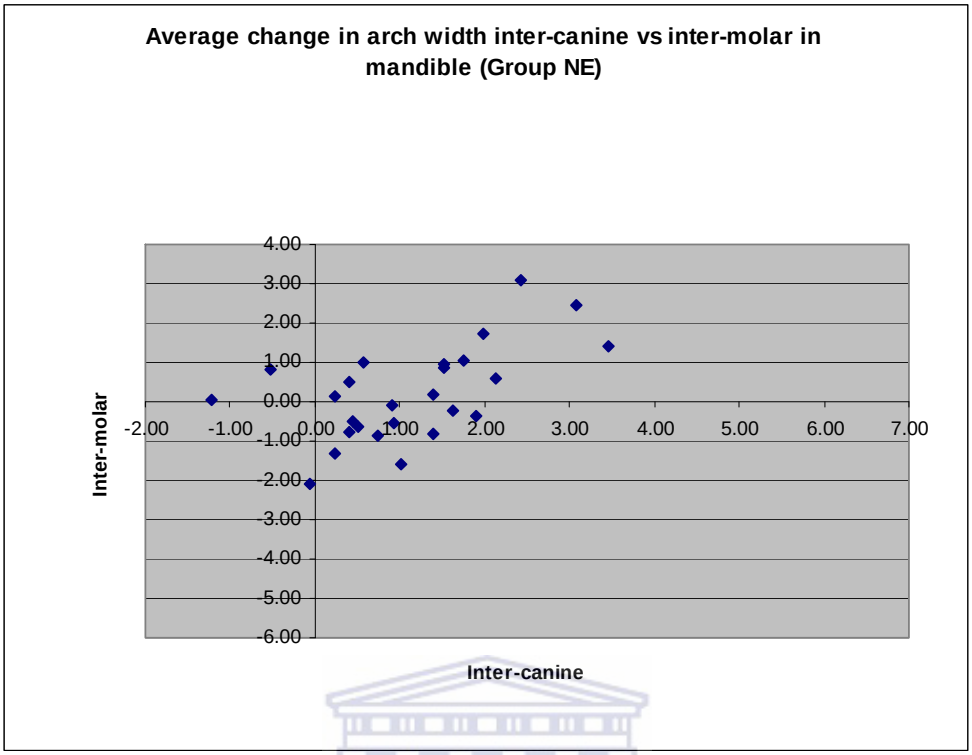

Figure 23
Average change in arch width inter-canine vs. inter-molar in mandible (Group NE).

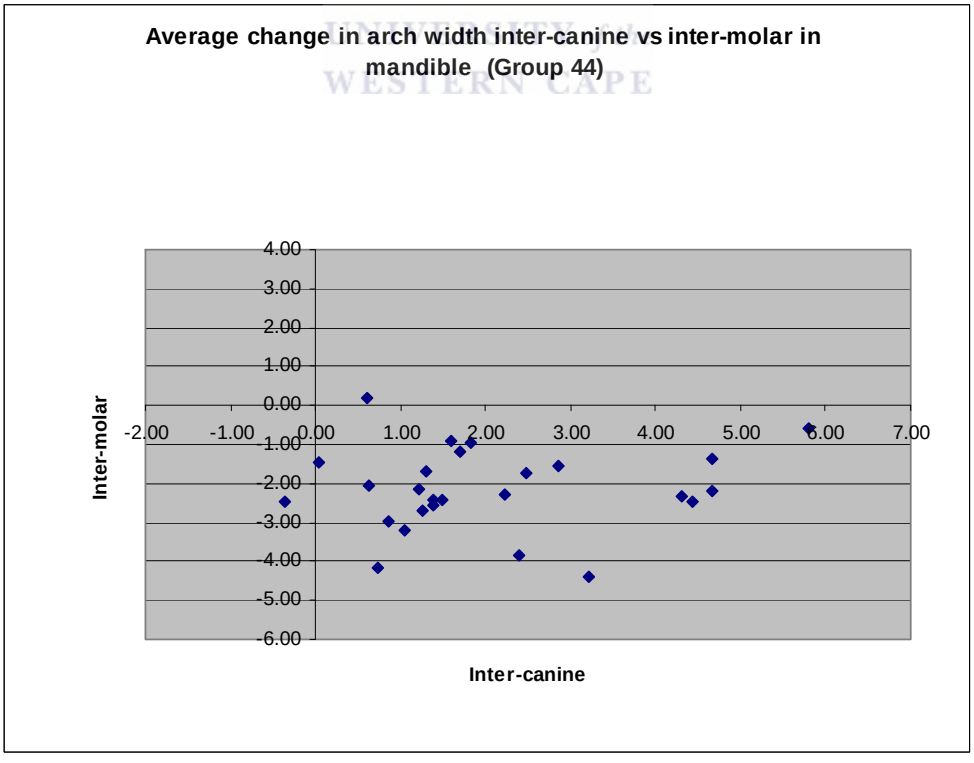

Figure 24
Average change in arch width inter-canine vs. inter-molar in mandible (Group 44).

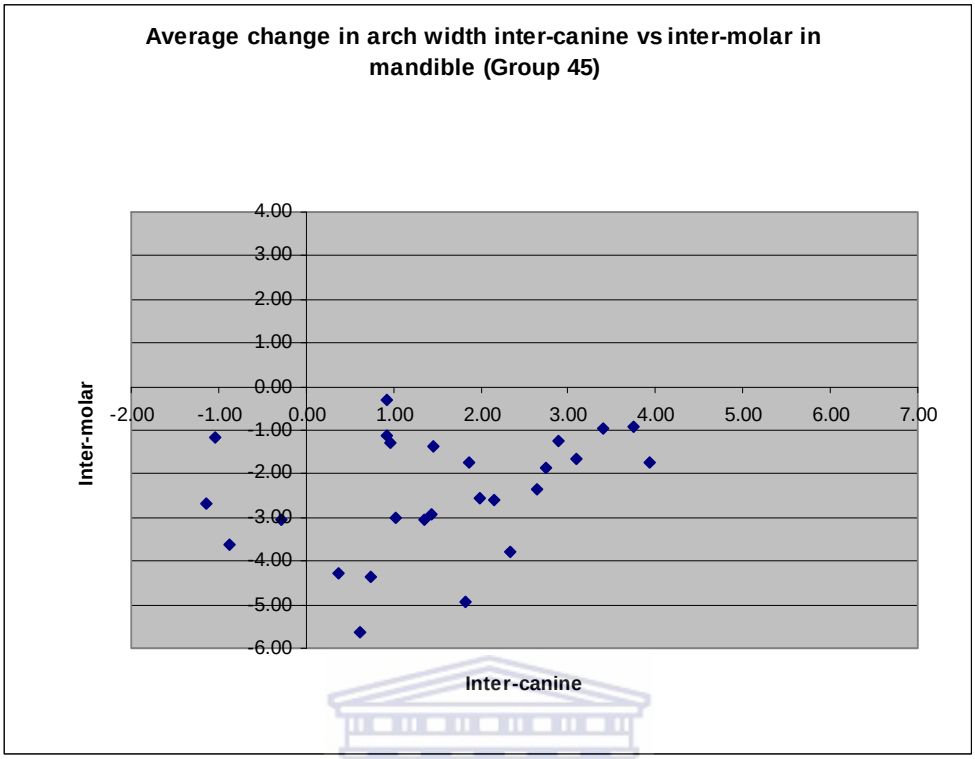

Figure 25
Average change in arch width inter-canine vs. inter-molar in mandible (Group 45).

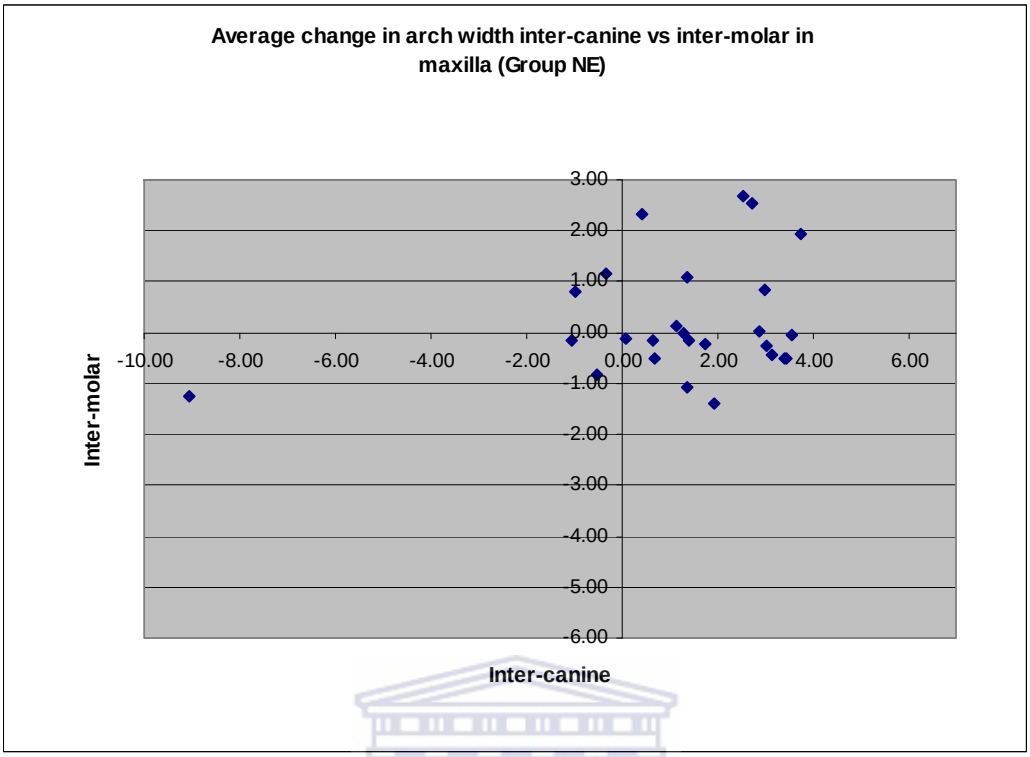

Figure 26
Average change in arch width inter-canine vs. inter-molar in maxilla (Group NE).

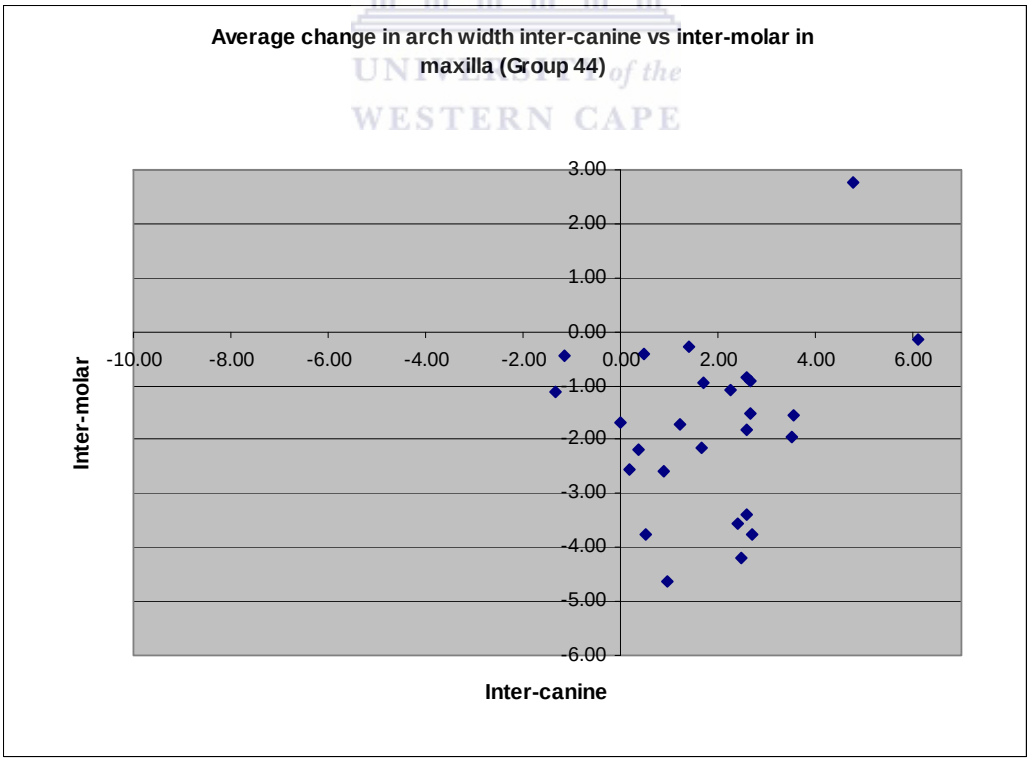

Figure 27
Average change in arch width inter-canine vs. inter-molar in maxilla (Group 44).

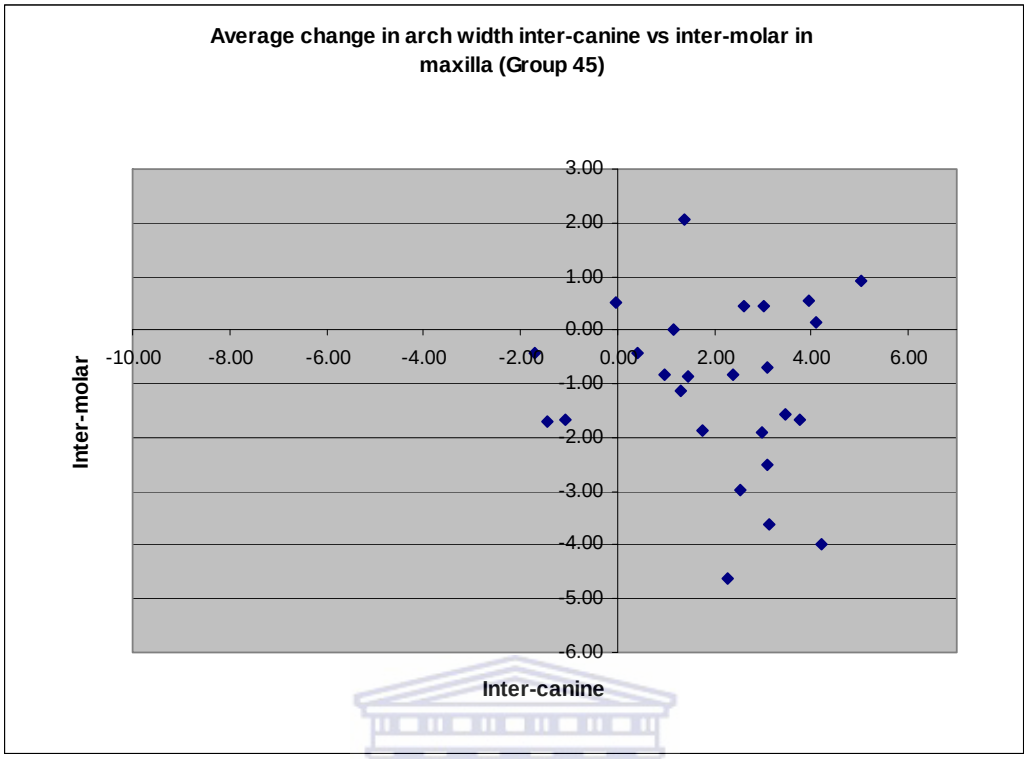

Figure 28
Average change in arch width inter-canine vs. inter-molar in maxilla (Group 45).

Chapter 5

DISCUSSION

It is clear that there are changes that occur in the arch dimensions with orthodontic treatment (Paquette, Beattie and Johnston 1992, Bishara et al 1994, Heiser et al 2004, Taner et al 2004, Isik et al 2005 and Aksu and Kocadereli 2005). This study investigated the changes which occur in arch width and arch length in non-extraction and extraction cases. The research did not study long-term stability of the different types of treatment. The three treatment groups in this study were: non-extraction (Group NE), extraction of first premolars (Group 44) and extraction of upper first and lower second premolars (Group 45).

5.1 Age comparison and average treatment period

On average Group NE started treatment earlier than the two extraction groups. Group NE was also the group with the shortest treatment period. In Group 45 treatment on average started later and the treatment period was also longer compared to the other two groups.

Data gathered from the literature indicates that the average age when treatment is started for non-extraction orthodontic treatment is between 10.9 years and 14.21 years (Paquette, Beattie and Johnston 1992, Bishara et al 1994, Heiser et al 2004, Taner et al 2004, Isik et al 2005 and Aksu and Kocadereli 2005). For extraction treatment the average age when treatment is started is between 11.5 years and 14.3 years (McReynolds and Little 1991, Paquette, Beattie and Johnston 1992, Bishara et al 1994, Shearn and Woods 2000, Boley et al 2003, , Heiser et al 2004, Isik et al 2005 and Aksu and Kocadereli 2005). In the current study the average age when treatment was started was 13.73 years for Group NE, 13.93 years for Group 44 and 14.62 years for Group 45. In Group 45, the average age at which treatment started was later compared with the studies in the literature.

Data gathered from the literature indicates that the average treatment period for non-extraction orthodontic treatment is between 1.6 years and 3 years (Paquette, Beattie and

Johnston 1992, Bishara et al 1994, Kim and Gianelly 2003, Heiser et al 2004, Taner et al 2004 and Aksu and Kocadereli 2005). For extraction treatment the average treatment period reported is between 1.84 years and 3.1 years (McReynolds and Little 1991, Paquette, Beattie and Johnston 1992, Bishara et al 1994, Shearn and Woods 2000, Boley et al 2003, Kim and Gianelly 2003, Heiser et al 2004 and Aksu and Kocadereli 2005). In the current study the average treatment period was 1.84 years for Group NE, 1.97 years for Group 44 and 2.29 years for Group 45. For the current study the treatment period is generally in agreement with those described in the literature.

5.2 Comparison of arch widths measured on pre-treatment study models

5.2.1 Males compared with females

Mandible and Maxilla

The males had larger average arch width measurements pre-treatment for all three treatment groups, except for some areas in Group 44. In the latter group the males mostly showed greater average arch widths except in the mandibular inter-first and inter-second premolar areas, where the values did not differ significantly from those of the female group. For the mandibular inter-molar, maxillary inter-first premolar and maxillary inter-molar arch widths the females had greater average arch widths in Group 44. Some of these findings are in accordance with those of Knott (1972) who found that the average size of the dental arch was greater for males than for females.

In this study an equal number of males and females were included to balance the study samples. As the study sample was not very large the differences for males and females will not be discussed in detail. Most studies on arch width and arch length changes during orthodontic studies in the literature have not studied the differences in males and females.

5.2.2 Average of combined samples for mandibular and maxillary arch width

Pre-treatment values in the mandibular arch showed almost similar values for Group NE, group 44 and group 45, except for the inter-second premolar arch width where Group NE had the largest average inter-second premolar arch width and Group 44 the smallest average inter-second premolar arch width.

In the maxilla the pre-treatment values of Group NE and Group 45 were almost similar for the inter-canine arch width, with Group 44 showing the greatest inter-canine arch width. In the inter-first premolar, inter-second premolar and inter-molar arch widths Group 44 showed the greatest arch width, with Group 45 showing the smallest arch width.

5.3 Average vs. Standard Deviation of the three treatment groups for the arch width in the intercanine and intermolar areas

The studies found in the literature did not compare the average and the standard deviation for the arch width measurement. In the present study the average inter-canine arch width increased in both the mandible and maxilla for all three treatment groups. The average inter-molar arch width in the mandible and maxilla decreased in the two extraction groups. The non-extraction group showed a slight increase in both the mandible and maxilla for the average inter-molar arch width. Studies by Shapiro (1974), Gardner and Chaconas (1976), Kim and Gianelly (2003) and Gianelly (2003) found similar results for the average arch width changes in the inter-canine and inter-molar areas during orthodontic treatment.

5.4 Average change in arch width in mandible

5.4.1 Mandibular arch width

In some width parameters the mandible and maxilla showed similar overall trends for both the extraction and nonextraction groups, e.g., the inter-canine arch width increased for all three treatment groups, but the inter-molar arch widths increased in the non-extraction group and decreased in both extraction groups.

Inter-canine arch width

The data showed that the average mandibular inter-canine arch width increased in all three treatment modalities (Table 33). The most significant increase was in Group 44, being 2.07mm. Studies conducted by numerous researchers, including Shapiro (1974), Gardner and Chaconas (1976), Paquette, Beattie and Johnston (1992) and Luppanapornlap and Johnson (1993) showed similar changes for the average mandibular inter-canine arch width in their extraction and non-extraction samples. Isik et al (2005), however, found an average decrease of 0.6mm in mandibular inter-canine arch width with non-extraction treatment. These authors suggest that this may be due to the arch form being shaped so as to retain the inter-canine distance at the start of the treatment. They further suggest that some space may also be attained through stripping when necessary, and thus the decrease in arch width (Isik et al 2005). Sadowsky et al (1994) showed a 2.4mm increase in average mandibular inter-canine arch width. In their study some patients received expansion treatment and some also received rapid maxillary expansion. Glenn, Sinclair and Alexander (1987) studied non-extraction cases, and the combined findings of their Class1 and Class11 samples for mandibular canine widths are in accordance with our study sample. Their results showed an increase in average inter-canine arch width of 0.6mm. The present study showed a 1.11mm increase in average inter-canine arch width. Aksu and Kocadereli (2005) found an increase in average mandibular inter-canine arch width of 1.02mm, and they stated that the increase in

mandibular inter-canine arch width in non-extraction patients can be explained by a minimal expansion with the archwires.

If the premolars are extracted, the canines are shifted into a wider part of the arch, and an increase in the average arch width can therefore be expected in the extraction samples. McReynolds and Little (1991) showed that cases treated with mandibular second premolar extractions, experienced an increase in the average mandibular inter-canine arch width of 0.7mm. The result of our study appears to support these findings.

Group 44 showed an increase of 2.07mm and group 45 showed an increase of 1.50mm in average mandibular inter-canine arch width.

Inter-first premolar arch width

In Group NE the increase in average arch width in the mandibular first premolar region was in agreement with the average 1.62mm increase reported by Kim and Gianelly (2003), the 1.66mm average increase reported by Weinberg and Sadowsky (1996) and the 1.97mm average increase reported by Taner et al (2004). Isik et al's (2005) study showed an average increase 0.75mm, which is less than the findings of the current study. Gardner and Chaconas (1976) and Sadowsky et al (1994) showed a greater average increase of 2.96mm and 2.8mm respectively. Gardner and Chaconas (1976), Sadowsky et al (1994), Weinberg and Sadowsky (1996) and Taner et al (2004) attribute these findings to expansion treatment. Weinberg and Sadowsky (1996) state that a number of patients in their study received expansion treatment in the maxillary arch with reciprocal expansion in the mandibular arch.

The increase of 2.45mm in the inter-first premolar arch width in the mandible for Group 45 is a significant increase. Unfortunately, this could not be compared with other studies as we could not retrieve any published literature to support or dispute this. In group 44 the first premolars were extracted.

Some of the studies in the literature used samples where four first premolar extractions had been done, but the inter-premolar arch width had not been measured (Bishara et al 1994, Bishara 1973). In other studies there was no indication of which premolars had been extracted (Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993, Aksu and Kocadereli 2005). The findings of these studies could not, therefore, be compared with the results of this research.

Inter-second premolar arch width

The changes in inter-second premolar arch width in Group NE were in agreement with findings in the study by Isik et al (2005) and showed an increase in the inter-second premolar mandibular arch width. In the current study the average increase in inter-second premolar arch width was 0.93mm. Gardner and Chaconas (1976), Sadowsky et al (1994) and Kim and Gianelly (2003) showed increases in inter-second premolar arch width of between 1.62mm and 2.8mm. These are greater than the increase found in the current study, but may be expected as Gardner and Chaconas (1976) and Sadowsky et al (1994) had patients that received expansion treatment in their samples.

The average mandibular inter-second premolar arch width showed a decrease of 1.66mm for Group 44. Studies by Gardner and Chaconas (1976), Kim and Gianelly (2003) and Isik et al (2005) also showed a decrease in average arch width in the mandibular second premolar area when the four first premolars were extracted. These changes may possibly be attributed to the treatment, where extraction of the first premolars allows forward movement of the second premolars and molars into a slightly narrower area of the dental arch.

Inter-molar arch width

In the study done by Aksu and Kocadereli (2005) the results in the non-extraction treatment groups are in agreement with the increased in average intermolar arch width of 0.19mm which was found in this research. Most of the other studies had an average inter-

molar arch width increase of between 1-2mm, which is significantly more than the increase in the present study (Gardner and Chaconas 1976, Paquette, Beattie and Johnston 1992, Isik et al 2005). Gardner and Chaconas (1976) state that in their study this increase can be expected as the buccal segments were expanded. Sadowsky et al (1994) showed the greatest increase with the average inter-molar arch width increasing 3.5mm. In their study some patients received expansion treatment and some also received rapid maxillary expansion. In Paquette, Beattie and Johnston (1992) and Isik et al's (2005) studies the non-extraction samples also received expansion treatment. Results of the research done by Luppanapornlap and Johnson (1993) and Gianelly (2003) differed in that they found a slight decrease in intermolar arch width in non-extraction treatment of between 0.13mm and 0.2mm. Gianelly (2003) did not find these changes statistically significant, and did not give reasons for this finding. Luppanapornlap and Johnson (1993) did not discuss this finding either, but discussed post-treatment changes. In the studies by Glenn, Sinclair and Alexander (1987) and Kim and Gianelly (2003) it was found that the average mandibular inter-molar arch widths were slightly greater than the measurements of this study. Their investigations showed an increase in average inter-molar arch width of between 0.81mm and 0.9mm. Glenn, Sinclair and Alexander (1987) studied non-extraction cases, and this finding was for their combined sample of Class1 and Class11 cases.

Weinberg and Sadowsky (1996) studied non-extraction cases and showed greater increase in the inter-molar arch widths when compared with the data of the mandibular arch of this study. In their study a number of patients received expansion treatment of the maxillary arch with reciprocal expansion in the mandibular arch. These authors state that according to the data of their study the molars showed no anteroposterior movement.

In the mandibular inter-molar area Group 44 and Group 45 both showed a significant decrease in inter-molar arch width of more than 2mm. In Group 45 the average arch width decreased more compared to Group 44, the average arch width decreasing 2.47mm for Group 45 and decreasing 2.15mm for Group 44. Studies by Gianelly (2003), Kim and Gianelly (2003), Isik et al (2005) and Aksu and Kocadereli (2005), on samples of four

first premolar extractions, also show decreases in inter-molar width. The decreases in these studies were not as much as found by the present study. The authors attribute these findings to the consolidation of the extraction spaces. Studies by Luppanapornlap and Johnson (1993) showed an intermolar decrease of more than 2mm in the mandibular first molar area, but this article does not state clearly which premolars were extracted. A study by McReynolds and Little (1991) showed that in cases treated with mandibular second premolar extractions, the mandibular inter-molar arch width showed a decrease of 2.1mm. These findings are in accordance with the data of this study.

Shearn and Woods (2000) evaluated the treatment effect of mandibular first and mandidular second premolar extractions, and their study showed that there was evidence that mandibular second premolar extractions lead to a greater reduction in intermolar arch width. A reduction of 4.4mm in inter-molar arch width with mandibular second premolar extractions was shown in their study. This is a considerably greater reduction than the average reduction of 2.47mm derived from the data of this study. With mandibular first premolar extractions Shearn and Woods (2000) found the inter-molar arch width to decrease with 2.8mm. Shearn and Woods (2000) had 55 patients in their lower second premolar extraction group, with accompanying upper first or upper second premolar extractions for the sample.

5.5 Average change in arch width in maxilla

5.5.1 Maxillary arch width

Inter-canine arch width

The change in average inter-canine arch width in Group NE, (an average increase of 1.22mm), was in agreement with the increase shown in studies by Paquette, Beattie and Johnston (1992), Luppanapornlap and Johnson (1993), Isik et al (2005) and Aksu and Kocadereli (2005). Sadowsky et al (1994) showed the greatest increase with the average inter-canine arch width increasing 3.1mm. In their study some patients received expansion treatment and some received rapid maxillary expansion.

In the two extraction samples the increase in average arch width in the canine area was significantly larger compared with the non-extraction sample, being 1.84mm for Group 44 and 2.07mm for Group 45. From this data, Group 45 showed more of an increase in average inter-canine arch width compared with Group 44. Studies by Luppanapornlap and Johnson (1993), Isik et al (2005) and Aksu and Kocadereli (2005) show similar increases in inter-canine arch width in their extraction samples. In other studies done by Ho and Kerr (1987), Paquette, Beattie and Johnston (1992), Boley et al (2003) and Kim and Gianelly (2003) the extraction samples also show an increase in the maxillary inter-canine arch width, but the increase is 1mm and less. In the extraction samples an increase in the arch width can be expected as the canines are shifted into a wider part of the arch.

Inter-first premolar arch width

The average arch width in the first premolar region of Group NE showed a statistically significant increase of 2.64mm. This is in agreement with studies by Isik et al (2005) which showed a 2.15mm increase, Sadowsky et al (1994) which showed a 3.0mm increase and Kim and Gianelly (2003) which showed an increase of 2.1mm in the first premolar region of their nonextraction samples. Taner et al (2004) showed a greater

increase, with an average of 4.33mm, in their maxillary interpremolar arch widths with nonextraction treatment. In their study, however, all patients received expansion treatment.

Inter-second premolar arch width

Group NE showed an average increase of 2.10mm in inter-second premolar arch width. Kim and Gianelly (2003) reported an increase of 2.1mm and Isik et al (2005) an increase of 2.11mm in maxillary inter-second premolar arch width for their non-extraction samples. Kim and Gianelly (2003) stated that large increases in the second premolar areas in non-extraction treatment can be expected, because non-extraction treatment should be expansionary to avoid creating crossbites in the buccal segments of the maxillary arch. Taner et al (2004) and Sadowsky et al (1994) showed an increase in inter-second premolar arch width of 3.95mm and 4.6mm respectively. In Taner et al's (2004) study all patients received expansion treatment and in Sadowsky et al's (1994) study some patients received expansion treatment and others received rapid maxillary expansion.

Both extraction samples showed a decrease in the average inter-second premolar arch width in the maxillary arch. Group 44 showed a statistically significant greater decrease in average arch width in this area compared with Group 45. The decrease in the average inter-second premolar arch width of 0.29mm for Group 45 was not statistically significant, but the decrease of 1.01mm for Group 44 was statistically significant. The study by Kim and Gianelly (2003) where four first premolars had been extracted showed a decrease in average arch width of 0.76mm. This is agreement with the data of this study which shows an average decrease of 1.01mm in inter-second premolar arch width for Group 44.

In their studies, Isik et al (2005) and Ho and Kerr (1987) found the inter-premolar arch width in the maxillary arch to increase with extraction treatment. These studies showed only slight increases of between 0.03mm and 0.44mm. These slight increases can be

compared with the slight decrease in interpremolar width shown by Group 45, as the actual values are small.

Inter-molar arch width

Group NE showed a slight increase of 0.23mm in the average maxillary inter-molar arch width. Studies by Paquette, Beattie and Johnston (1992), Luppanapornlap and Johnson (1993), Sadowsky et al (1994), Kim and Gianelly (2003), Taner et al (2004), Isik et al (2005) and Aksu and Kocadereli (2005) showed a significantly greater increase in average maxillary inter-molar arch width. The increases in inter-molar arch widths measured in these studies vary between 1.45mm-5.4mm. This may be attributed to expansion treatment in the non-extraction samples of these studies.

In the inter-molar region for the maxilla both the extraction samples showed a decrease in average arch width, with the Group 44 showing a significantly greater decrease in average arch width. In Group 44 the average intermolar arch width decreased by 1.79mm compared with the average decrease of 1.09mm in Group 45. Studies done by Ho and Kerr (1987), Luppanapornlap and Johnson (1993), Kim and Gianelly (2003), Boley et al (2003), Isik et al (2005) and Aksu and Kocadereli (2005) all showed a decrease in average inter-molar arch width in their extraction samples. In the first two of these studies, the extraction samples consisted of patients who had first premolar extractions. In the study by Isik et al (2005) the decrease in average intermolar arch width was 0.88mm and in the study by Kim and Gianelly (2003) the average decrease was 0.53mm. This was markedly less than the 1.79mm average decrease found in the present study for Group 44. Expansion treatment together with the extraction treatment could be the reason for the increase in inter-molar arch width in their study. Paquette, Beattie and Johnston (1992) differed and found an almost imperceptible increase in average maxillary inter-molar width of 0.1mm. They did not give a reason for their finding.

5.6 Arch length

5.6.1 Pre-treatment study model comparison of arch length

The male samples had longer average arch lengths pre-treatment compared with the female samples for all three treatment groups. In the mandible Group 45 showed the longest average arch length with Group NE showing the shortest average arch length. In the maxilla Group 44 showed the longest average arch length with Group 45 showing the shortest average arch length.

The studies found in the literature did not compare the pre-treatment study model arch length.

5.6.2 Post-treatment study model comparison of arch length

In Group NE the average arch length increased in the mandible and was essentially unchanged in the maxilla. Group 44 and Group 45 showed a decrease in average arch length for both the mandibular and maxillary arches.

5.7 Average vs. Standard Deviation of the three treatment groups for arch length in the mandibular and maxillary arches

The studies found in the literature did not compare the average and the standard deviation for the arch length measurement. For Group NE there was an increase of 1.99mm in average mandibular arch length and a decrease of 0.05mm in average maxillary arch length. Glenn, Sinclair and Alexander (1987) and Paquette, Beattie and Johnston (1992) also showed an increase in mandibular average arch length in their non-extraction group.

The amount of arch length decrease during treatment depends to a large extent on whether extraction or non-extraction treatment is used (Shapiro 1974). As can be expected, arch length decreased more in the extraction cases than the non-extraction

cases. In the maxillary and mandibular arches there was a decrease in average arch length changes post-treatment for both Group 44 and Group 45.

5.8 Average change in arch length

5.8.1 Mandibular arch length

Group NE of the present study showed an increase in average arch length of 1.99mm in the mandibular arch. Glenn, Sinclair and Alexander (1987), Heiser et al (2004) and Sadowsky et al (1994) also showed an increase in average arch length mandibular in their studies, but of only 0.2mm, 0.59mm and 0.6mm respectively. Paquette, Beattie and Johnston (1992) reported an increase of 2.9mm which is greater than the increase of the current study. Some studies have however shown a decrease in average mandibular arch length in non-extraction samples. Shapiro (1974) showed an average arch length decrease of 0.7mm and Luppanapornlap and Johnson (1993) showed a decrease of 0.2mm in mandibular arch length.

Group 44 showed a decrease of 9.64mm in average arch length. Shearn and Woods (2000) showed a decrease in average mandibular arch length of 11.1mm with first premolar extractions.

Group 45 in this study showed a decrease of 10.93mm in average arch length, which is a relatively similar value to that of Shearn and Woods (2000) which showed a decrease in average mandibular arch length of 11.6mm with second premolar extractions, and McReynolds and Little (1991) which showed a decrease in average arch length of 11.0mm with mandibular second premolar extractions.

Paquette, Beattie and Johnston (1992) showed a decrease of 9.1mm, Luppanapornlap and Johnson (1993) showed a decrease of 8.6mm and Shapiro (1974) also showed a decrease of 8.3mm in average mandibular arch length in their extraction groups. These studies did not specify which premolars had been extracted. In the present study the average arch

length of the extraction groups decreased more compared with these studies. Luppanapornlap and Johnson (1993) and Paquette, Beattie and Johnston (1992) studied Class 11 patients and Shapiro's (1974) sample included Class 11 patients. Some of these patients received expansion treatment together with extraction treatment, and this may be a reason why the decrease in arch length was less than that of the current study. Heiser et al (2004) showed a decrease of 12.1mm, but they did not specify which premolars were extracted.

The studies by Ho and Kerr (1987) and Boley et al (2003) showed a decrease in mandibular arch length during treatment of 3.36mm and 4.6mm respectively. This is significantly less than the findings of this study but may be due to a different method being used to determine the arch length. Ho and Kerr (1987) used the method where a line from the contact area of the incisors to the midpoint of a line that connected the distal contact areas of the first molars was measured. Boley et al (2003) measured the arch length in a similar manner but to the midpoint of a line between the mesial contacts of the first molars.

5.8.2 Maxillary arch length

In the maxillary arch Group NE showed a slight decrease of 0.05mm in average maxillary arch length. Luppanapornlap and Johnson (1993) and Sadowsky et al (1994) showed a decrease in maxillary arch length of 0.9mm and 0.1mm respectively for their nonextraction groups. Paquette, Beattie and Johnston (1992) and Heiser et al (2004) differed in that there was an increase in average maxillary arch length of 1.7mm and 3.2mm respectively in their non-extraction group. A possible reason for some of these differences may be that cases included in the studies had different maxillary arch space deficiencies. Paquette, Beattie and Johnston (1992) and Heiser et al's (2004) studies included Class 11 patients and expansion treatment was often included in the treatment planning. The increase in maxillary arch length in their study may be partly attributed to the expansion treatment.

In the present study the arch length of Group 44 decreased 12.07mm and Group 45 decreased 12.41mm in the maxillary arch. Paquette, Beattie and Johnston (1992) showed a decrease of 11.6mm in average maxillary arch length in their extraction sample. Luppanapornlap and Johnson (1993) showed a decrease of 8.3mm in average maxillary arch length in their extraction sample. Heiser et al (2004) showed a decrease of 9.64mm.These studies did not specify which premolars were extracted. The decrease in average arch length in the present study is more than the decreases in these studies. Ho and Kerr (1987) and Boley et al (2003) in their studies showed a decrease of 4.93mm and 6.5mm respectively. Ho and Kerr's (1987) study did not specify which premolars were extracted and Boley et al (2003) had different premolar extraction patterns. Their findings are significantly less than the findings of this study, but as mentioned may be due to a different method being used to determine the arch length. Some other possible reasons for the differences reported among the various studies could be differences in initial arch length deficiencies and treatment resulting in proclination and retroclination of anterior teeth.

When comparing the two extraction samples, Group 45 showed a greater decrease in both the mandible and maxilla. When comparing the mandible to the maxilla, both extraction groups showed a greater decrease in arch length in the maxilla.

5.9 Summary

When comparing the average mandibular arch width changes, all values in Group NE showed an increase, whilst the inter-second premolar and inter-molar arch widths of the two extraction groups which showed a decrease in arch width (Table 33). In the maxillary arch a similar effect was observed as all values showed an increase, except the inter-premolar and inter-molar values of the extraction groups. The decrease in average inter-premolar and inter-molar arch widths may be the result of teeth being extracted and then the other teeth being shifted into a narrower part of the dental arch (Paquette, Beattie and Johnston 1992, Luppanapornlap and Johnson 1993).

In both extraction and non-extraction treatment there was an increase in the average inter-canine arch width in the mandible and maxilla. The extraction groups showed more of an increase compared with the non-extraction group. From this it is evident that extraction treatment does not necessarily lead to narrowing of the dental arches.

Group 45 showed a greater decrease in average mandibular arch width as well as greater decrease in average mandibular arch length when compared with Group 44. These changes may be due to relatively more mesial movement of the molars into the extraction space during orthodontic treatment in the group where maxillary first and mandibular second premolars were extracted. Of the two extraction samples Group 44 showed a greater decrease in average maxillary arch width and Group 45 showed a slightly greater arch length decrease in the maxilla.

5.6 Limitations of the study

- This study was not limited to a certain malocclusion. Some of the studies in the literature were limited to certain malocclusions, with Class 11 malocclusions being studied more often.
- The tooth size arch length deficiency was not brought into this study.
- The sample size of males and females was small. The sample sizes of both males and females have to be increased to study gender differences.
- The post retention stability of treatment was not considered.

Chapter 6

CONCLUSION

The conclusions of the research can be summarized as the following:

- The average inter-canine arch width increased during treatment in all three treatment modalities, more so in the two extraction groups. The changes in inter-canine arch width for all three treatment groups, for both the mandibular and maxillary arches were significant ($p<0.05$). The differences in changes between Group 44 and Group 45 were not significant ($p>0.05$).

- Group NE showed statistically significant increases in inter-premolar arch width for both the mandible and maxilla. The two extraction groups showed different trends for the arch width changes in the mandibular premolar region. Group 45 showed an increase in arch width in the mandibular first premolar area, whereas Group 44 showed a decrease in the mandibular second premolar area. In the maxillary arch both extraction groups showed a decrease in arch width in the second premolar area, with Group 44 showing a greater decrease in arch width. The changes in inter-premolar arch widths were significant for all three treatment groups for the mandibular and maxillary arches ($p<0.05$), except in the inter-second premolar arch width of the maxillary arch where the change was not significant ($p>0.05$). The differences in changes between Group 44 and Group 45 were not significant ($p>0.05$).

- The average inter-molar arch width increased slightly in Group NE, and decreased in both the extraction groups. For Group NE the change in average inter-molar arch width was not statistically significant ($p>0.05$). For both Group 44 and Group 45 the changes in average inter-molar arch width were statistically significant ($p<0.05$). In the mandibular arch the average inter-molar arch width

decreased more in Group 45 compared with Group 44. The changes in the mandibular intermolar arch width between Group 44 and Group 45 were not significant ($p>0.05$). In the maxillary arch Group 44 showed a greater decrease in inter-molar arch with. The changes between Group 44 and Group 45 in average maxillary inter-molar arch width were statistically significant at the 90% level of significance ($p=0.0594$). When extracting mandibular second premolars the data shows that the mandibular inter-molar arch width decreases more, and the arch length also decreases more, compared with the effects when extraction of mandibular first premolars is the treatment plan.

- The average mandibular arch length increased during treatment in Group NE. The average maxillary arch length in Group NE was essentially unchanged. For both the mandible and maxilla Group 45 showed a greater decrease in average arch length when compared with Group 44. The mandibular and maxillary changes in arch length for Group NE and both extraction groups were statistically significant ($p<0.05$), except in the maxillary arch of Group NE where there was no statistically significant difference ($p>0.05$). The differences in changes between Group 44 and Group 45 were not significant ($p>0.05$).

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Appendix A

Form on which arch width and arch length measurements were captured

PATIENT NR & TREATMENT GROUP: _____
AGE AT START OF TREATMENT: _____
DATE AT START OF TREATMENT: _____
DATE AT END OF TREATMENT: _____
GENDER: _____

PRE-TREATMENT ARCHWIDTH

MANDIBLE:	INTER-CANINE	INTER-1ST PREM	INTER -2ND PREM	INTER-MOL1ST
1st measurem				
2nd measurem				
3rd measurem				
MEAN				

PRE-TREATMENT ARCH LENGTH MANDIBLE : 1st A+B_____
2nd A+B _____ 3rd A+B _____ MEAN_____

POST-TREATMENT ARCHWIDTH

MANDIBLE: :	INTER-CANINE	INTER-1ST PREM	INTER -2ND PREM	INTER-MOL1ST
1st measurem				
2nd measurem				
3rd measurem				
MEAN				

POST-TREATMENT ARCH LENGTH MANDIBLE: 1st A+B _____
2nd A+B _____ 3rd A+B _____ MEAN _____

PRE-TREATMENT ARCHWIDTH

MAXILLA	INTER-CANINE	INTER-1ST PREM	INTER -2ND PREM	INTER-MOL1ST
1st measurem				
2nd measurem				
3rd measurem				
MEAN				

PRE-TREATMENT ARCH LENGTH MAXILLA: 1st A+B _____
2nd A+B _____ 3rd A+B ____ MEAN _____

POST-TREATMENT ARCHWIDTH

MAXILLA	INTER-CANINE	INTER-1ST PREM	INTER -2ND PREM	INTER-MOL1ST
1st measurem				
2nd measurem				
3rd measurem				
MEAN				

POST-TREATMENT ARCH LENGTH MAXILLA: 1st A+B _____
2nd A+B _____ 3rd A+B _____ MEAN ____

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