EFFECTIVENESS OF MANUAL TOOTHBRUSHES IN PATIENTS WITH FIXED ORTHODONTIC APPLIANCES

by

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BSc, BDS, MSc (Wits)

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MChD (ORTHODONTICS)

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I hope you take great care of your mouth and teeth,
and that you clean them well every morning with
a sponge and tepid water, with a few drops of
arquebusade water dropped into it;
besides washing your mouth carefully after every meal.
I do insist upon your never using those sticks, or any
hard substance whatsoever, which always rub away
the gums, and destroy the varnish of the teeth.

Lord Philip Stanhope Chesterfield
Letter to his son, February 15, 1754

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DECLARATION

I, Ashraf Laher, declare that **Effectiveness of Manual Toothbrushes in Patients with Fixed Orthodontic Appliances** which I herewith submit to the University of Pretoria for the MChD (Orthodontics) degree has not previously been submitted by me to any other university.

	20/3/00
ASHRAF LAHER	DATE

DEDICATION

To my parents, who gave me the
opportunity to succeed

and

To my wife, Tayyeba
and sons, Muhammed and Ebrahim,
for their love, support and understanding

SUMMARY

EFFECTIVENESS OF MANUAL TOOTHBRUSHES IN PATIENTS WITH FIXED ORTHODONTIC APPLIANCES

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Maintaining good oral hygiene is a challenge for anyone, but particularly for orthodontic patients whose appliances make them more susceptible to gingivitis, hyperplastic tissue, decalcification and dental caries.

The aim of this study was to evaluate:

i) the effectiveness of 4 different manual toothbrushes in patients with fixed orthodontic appliances
ii) the correlation of the Index of Oral Cleanliness (IOC) to both the Plaque Index (PI) and Gingival Index (GI) and
iii) to determine whether patient toothbrush preference is directly related to plaque control.

A single-blind, cross-over study design was used to evaluate the toothbrushes. The brushes evaluated were Orthodontic Oral B, Oral B Advantage 30, Colgate Precision and Aquafresh. Forty-six patients, aged 11 to 27, undergoing fixed orthodontic appliance therapy were screened and recruited with parental consent. These patients were randomly allocated into 4 groups. All the patients were given a scale and polish at week 0. Baseline recordings of PI, GI and IOC were done 4 weeks later and the first toothbrush given. After using the toothbrush for a period of 2 weeks the PI, GI and IOC were again recorded and the patients had another scale and polish. A period of 4 weeks elapsed before new baseline recordings were done and the sequence followed as described for the next toothbrush. This was done until all patients had used all 4 toothbrushes. At the end of the clinical trial, each patient was asked about their toothbrush preference.

The results showed that the PI and GI values were relatively low at baseline as well as after the use of the toothbrushes. The Brown and Forsyths test for equality of variance was done to enable testing of means. General linear model procedure showed no statistical difference in Mean Plaque Index (MPI) before and after, and Difference in Mean Plaque Index (DMPI) amongst the 4 toothbrushes. There was a slight difference in the Difference in Mean Gingival Index (DMGI) between the Colgate Precision and Aquafresh toothbrush. For all the other comparisons general linear model procedure showed no difference in MGI (before) and MGI (after).

Pearsons Correlation analysis showed that the IOC was significantly correlated to the PI, but this correlation was not perfect. The high level of correlation indicates that the IOC can be used as a screening procedure in orthodontic patients. There was no correlation between the IOC and GI.

There was no correlation between patients preferred toothbrush and effectiveness of oral hygiene as measured by DMPI and DMGI.

OPSOMMING

DOELTREFFENDHEID VAN NIE-OUTOMATIESE TANDEBORSELS IN PASIëNTE MET VASTE ORTODONTIESE APPARAAT

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Die handhawing van goeie mondhigiëne is 'n uitdaging vir enige pasiënt, maar veral vir ortodonsie pasiënte waar hierdie apparate hulle vatbaarheid vir gingivitis, hiperplastiese weefsel, dekalsifikasie en tandkaries verhoog.

Die doel van die studie was om die volgende te evalueer:

i) die effektiwiteit van 4 verskillende nie-outomatiese tandeborsels in pasiënte met vaste ortodonsie apparaat.
ii) die korrelasie van die "Index of Oral Cleanliness" (IOC) met beide die Plaak Indeks (PI) en Gingivale Indeks (GI) en
iii) om te bepaal of pasiënt voorkeur vir 'n tandeborsel direk verband hou met plaakbeheer.

'n Enkle blinde ("single blind"), uitruilingstudie ("cross-over") ontwerp is gebruik om die tandeborsels te evalueer. Die tandeborsels wat evalueer is was die Orthodontic Oral B, Oral B Advantage 30, Colgate Precision en Aquafresh. Nadat siftingsondersoeke uitgevoer is, is ses-en-veertig pasiënte tussen die ouderdomme van 11 en 27 gewerf nadat

toestemming van die ouers is verkry is. Hierdie pasiënte was almal onder vaste ortodonsie toestel terapie en is ewekansig in 4 groepe ingedeel. Alle pasiënte het 'n skalering en polering ontvang gedurende week 0. Basislynmetings van PI, GI en IOC is 4 weke later gedoen en die eerste tandeborsel is aan die pasiënte uitgedeel. Nadat die tandeborsel vir 'n periode van 2 weke gebruik is, is die PI, GI en IOC weer gemeet en 'n skalering en poleer is weer uitgevoer. 'n Periode van 4 weke is toegelaat voordat nuwe basislynmetings gedoen is en dieselfde prosedure gevolg is vir die volgende tandeborsel. Dit is gedoen totdat al die pasiënte alvier tandeborsels gebruik het. Aan die einde van die kliniese studie is elke pasiënt uitgevra om die tandeborsel van voorkeur te bepaal.

Die resultate het getoon dat die PI en GI waardes relatief laag was tydens bepaling van die basislyndata, asook na gebruik van die tandeborsels. Die Brown en Forsyths toets vir gelykheid van variansie is gedoen om die gemiddeldes te toets. Algemene liniêre model prosedure het getoon dat daar geen statisties betekenisvolle verskil tussen Gemiddelde Plaakindeks (MPI) voor en na, en Verskil in Gemiddelde Plaakindeks (DMPI) tussen die 4 tandeborsels was nie. Daar was 'n geringe verskil in die Verskil in Gemiddelde Gingivale Indeks (VGGI) tussen die Colgate Precision en Aquafresh tandeborsels. Vir al die ander vergelykings het algemene liniêre model prosedure geen verskil getoon tussen MGI (voor) en MGI (na) nie.

Pearsons Korrelasie analise het getoon dat die IOC betekenisvol korreleer met die PI, maar dat die korrelasie nie perfek was nie. Die hoë vlak van korrelasie dui daarop dat die IOC gebruik kan word as 'n siftingsprosedure in ortodonsie pasiënte. Daar was geen korrelasie tussen die IOC en GI nie.

Geen korrelasie is gevind nie tussen die tandeborsel wat deur die meeste pasiënte verkies is en die effektiwiteit van mondhigiëne prosedures soos gemeet met die DMPI en DMGI.

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In the name of Allah, most beneficient, most merciful

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To all those whom I have unintentionally omitted without whose understanding this study would be incomplete.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ADA	American Dental Association
CAD	Computer Assisted Design
CPITN	Community Periodontal Index of Treatment Needs
DIOC	Difference in Index of Oral Cleanliness
DMF	Decayed, Missing and Filled
DMGI	Difference in Mean Gingival Index
DMIOC	Difference in Mean Index of Oral Cleanliness
DMPI	Difference in Mean Plaque Index
GI	Gingival Index
IAE	Interproximal Access Efficacy
IOC	Index of Oral Cleanliness
MGI	Mean Gingival Index
MIOC	Mean Index of Oral Cleanliness
MPI	Mean Plaque Index
NaF	Sodium Fluoride
PI	Plaque Index
PMA	Papilla-Margin-Attached Gingival Index
PTNS	Periodontal Treatment Need System
SEM	Scanning Electron Microscopy
UK	United Kingdom
WHO	World Health Organisation

CHAPTER 1: INTRODUCTION

1.1 Introduction

Maintaining good oral hygiene is a challenge for anyone, but particularly for orthodontic patients whose appliances make them more susceptible to gingivitis, hyperplastic tissue, decalcification and dental caries.

Lõe (1971) has shown that gingivitis can be reversed in 5 days through effective removal of plaque. Mechanical removal of plaque can be adequately achieved with a manual toothbrush. The use of electric toothbrushes by patients undergoing orthodontic treatment has also been reported amongst others by Heintze, Jost-Brinkman and Loundos (1996) and Trimpeneers *et al* (1997). The use of manual toothbrushes has been by far the most cost-effective way in maintaining good oral hygiene amongst orthodontic patients (Zachrisson, 1974).

Various other mechanical adjuncts such as oral irrigation have also been used to reduce the level of plaque in patients undergoing orthodontic treatment (Burch, Lanese and Ngan, 1994).

Other plaque control devices include the use of chemical agents. These agents are used during the active phase of orthodontic treatment to reduce bacterial plaque accumulation. According to Brightman *et al* (1991) the chemical agents should be used for orthodontic patients who have difficulty in maintaining plaque control by mechanical means alone. These patients should be reminded that the chemical agents are not substitutes for thorough brushing and interproximal cleaning. For most orthodontic patients these agents may be necessary only for short-term periods to demonstrate how proper oral hygiene feels as this would provide an incentive for the patients to redirect their oral hygiene methods.

1.2 Aim, Goals and Premise of the study

1.2.1 Aim

The aim of this study was to determine the effectiveness of four different manual toothbrushes in plaque control in a group of patients undergoing fixed orthodontic treatment.

1.2.2 Goals

The goals of this study were:

- to evaluate the effectiveness of four different manual toothbrushes using an established plaque and gingival index
- to validate the Index of Oral Cleanliness (IOC) as described by Bearn *et al* (1996), in patients undergoing fixed orthodontic treatment
- to determine whether patient toothbrush preference is directly related to plaque control.

1.2.3 Premise

A number of studies have reported on the most effective way in reducing plaque deposits around orthodontic brackets. Heintze *et al* (1996) evaluated 3 different types of electric toothbrushes during active appliance therapy and compared it to manual toothbrushing. They concluded that only the Rota-dent electric toothbrush showed statistically significantly lower plaque scores than the manual technique. For the other toothbrushes no differences were found compared to the manual toothbrushing technique.

Trimpeneers *et al* (1997) and Heasman *et al* (1998) also found no significant difference between electric and manual toothbrushes. Kiliçoglu, Yildirim and Polater (1997) investigated whether the specifically designed Orthodontic Oral B toothbrush was superior to the conventional Oral B Plus 35 toothbrush. Their results showed no difference between these two toothbrushes. However, the results must be interpreted with caution as only 20 patients were used in the cross-over design study.

The premise of this study is that there will be no difference in the effectiveness of the four manual toothbrushes tested in plaque control of patients undergoing fixed orthodontic therapy.

1.3 Delimitations and Limitations of the Study

1.3.1 Delimitations

The study was delimited to patients undergoing fixed Edgewise orthodontic treatment at the Oral and Dental Hospital, University of Pretoria. The age range of the patients was between 11-27 years. Details of patient selection will be discussed in Chapter 3.

1.3.2 Limitations

Limitations of the study were:

- Patients taking part in the study, had 9 extra appointments in addition to their regular orthodontic visits which might have interfered with their school.
- At the time of the study, there was no published research comparing different types of manual toothbrushes from various manufacturers amongst orthodontic patients thus no comparison could be made between various South African studies.
- Co-ordination of scaling and polishing appointments often led to the distribution of the "normal" oral hygiene programme at the Department of Oral Hygiene.
- Patients which seek treatment at the orthodontic department had a high dental knowledge which might explain the low baseline levels for the gingival and plaque indices as well as the small changes in before and after measurements.

1.4 Framework of Dissertation

CHAPTER 1 Introduction ↓
CHAPTER 2 Literature Review ↓
CHAPTER 3 Materials and Methods ↓
CHAPTER 4 Results ↓
CHAPTER 5 Discussion, Conclusion And Recommendations

1.5 Summary

Effective oral hygiene is one of the most important aspects in achieving optimal orthodontic results. With the ever increasing cost of oral health care world-wide, research carried out on the effectiveness of various manual toothbrushes may be significant in having cost-effective oral hygiene for orthodontic patients.

The aim, goals and premise of the study as well as delimitations and limitations explaining how the study was designed were discussed.

The impact of orthodontic treatment on caries and periodontal diseases, development of periodontal indices and studies where different toothbrushes were compared, effectiveness of toothbrushing on oral hygiene during fixed orthodontic treatment and effective oral hygiene for orthodontic patients will be reviewed and discussed in Chapter 2.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Patients undergoing fixed orthodontic treatment are at a higher risk of developing oral diseases such as dental caries and periodontal diseases. Various reports, including those of Zachrisson (1975), Boyd (1983) and O'Reilly and Featherstone (1987) have shown that orthodontic treatment is accompanied by an increased risk of caries. Legott *et al* (1984) and Huser, Baehni and Lang (1990) report an increased risk of gingivitis in patients undergoing orthodontic treatment. The primary cause of these lesions is considered to be the increased retention of plaque around fixed orthodontic appliances which creates an environment where effective oral hygiene is more difficult to achieve. These aspects together with effective oral hygiene modalities will be discussed.

2.2 Periodontal disease and orthodontic treatment

2.2.1 Pathogenesis of periodontal diseases

Epidemiological surveys, controlled clinical trials and basic research all indicate that periodontal disease is caused by the bacteria colonising the tooth surface (Lövdal *et al*, 1961; Russell, 1963; Löe, Theilade and Jensen, 1965; Lindhe, Hamp and Löe, 1975; Page and Schroeder, 1981). As long as the tooth surface is kept free of bacterial deposits, the gingiva will remain healthy, however if plaque is allowed to grow along the gingival margin, gingivitis will develop within a few weeks (Löe *et al*, 1965).

The next step in the pathogenesis of periodontal disease involves a spread of the supragingival plaque into a subgingival location. Thus, the contact area between the plaque and the gingival tissue becomes larger, resulting in an increased tendency for bleeding from the inflamed pocket wall. Destruction of the supragingival collagen fibres starts as soon as the dental plaque extends to a distance of less than 1mm from the apical border of the epithelial attachment. At the same time, alveolar bone resorbs at a distance of 2mm from the plaque. The progression of periodontal disease is thus determined by the rate of the apically directed growth of dental plaque. A well known example of rapid periodontal breakdown is that seen in juvenile periodontitis, in which a tooth may become totally detached from its bony socket before the affected individual reaches 20 years of age (Saxen, 1980).

The gingival/periodontal health status of young patients undergoing orthodontic treatment has been the focus of attention by orthodontists and periodontists alike. It might be reasonable to assume that poorly aligned teeth may complicate oral hygiene procedures and lead to increased plaque accumulation and subsequent gingival inflammation. (Davies *et al*, 1991)

Although there is no scientific basis to support the concern that orthodontic tooth movement may initiate gingivitis or cause periodontal attachment loss, it is generally conceded that the greater plaque-retentive nature of orthodontic appliances aids in the plaque accumulation at the gingival margin and thus may contribute to the incidence and severity of gingival inflammation (Zachrisson and Zachrisson, 1972). Most cases of gingivitis may remain stable for long periods of time. However, the progression of some gingivitis lesions to periodontitis, resulting in the irreversible loss of tooth-supporting tissues, has been well described. Page and Schroeder (1981) and Buckley (1980) observed that plaque was the primary etiologic agent in gingival disease, but when the amount of plaque and gingival disease was low, a statistically significant relationship was found between irregular teeth, plaque and gingival disease. This potential risk is unacceptable to many orthodontists and their patients. It is therefore logical to ensure good gingival and periodontal health before the commencement of orthodontic treatment. The ongoing monitoring of gingival and periodontal health by orthodontists throughout the treatment period and repeated reinforcement of acceptable oral hygiene routines have become an integral part of modern orthodontic practice. Numerous clinical studies have demonstrated the beneficial effect of an oral hygiene program carried out in conjunction with orthodontic treatment (Boyd, 1983; Cohen, Moss and William, 1983; McGlynn *et al*, 1987).

All of the mentioned studies have evaluated the short-term effects of orthodontic treatment on periodontal diseases. The next section deals with studies where the long-term effect of orthodontic treatment on periodontal health was studied.

2.2.2 Long-term effects of orthodontic treatment on periodontal health

It is widely believed that an important rationale for performing orthodontic treatment is to promote the health of the periodontium, thereby enhancing longevity of the dentition (Kessler, 1976). It is therefore assumed that adults with untreated malocclusions would be subject to a greater prevalence of periodontal disease than if their malocclusions had been corrected orthodontically. The relationship between malocclusion and periodontal disease has received much attention in the literature, with little support for such a relationship.

Conversely, it has been maintained that orthodontic treatment may have some adverse effects on the gingival and periodontal tissues which may hasten or promote periodontal breakdown in later life (Burkett, 1963). Most of the studies on the effects of orthodontic treatment on periodontal health have been concerned with the effects during treatment and up to a few years after treatment, with no long-term follow up. Also, most studies did not make use of a control group, which would be desirable to permit interpretation of the findings.

Zachrisson and co-workers (1972, 1973, 1974) reported on a study of fifty young patients with Class II, Division 1 malocclusions treated for an average of 19 months with extraction of four first premolars. The health of the periodontal tissues was evaluated periodically during and up to 2 years after treatment. Results were compared to a control group of similar teenagers who received no treatment. Despite good oral hygiene, a generalised moderate hyperplastic gingivitis was evident 1 to 2 months after appliance placement. This condition persisted throughout the treatment period and then improved during the first month after appliance removal. Since Stuteville (1937) reported his research, similar changes in the gingival tissues have been reported by many other authors, but the observations were limited to the period of active treatment or immediately after appliance removal. In Zachrisson's study, however, after 2 years of post-treatment follow-up, the orthodontic group demonstrated a slightly increased loss of periodontal attachment and alveolar bone compared to the untreated control group, but this was considered to be within acceptable limits. However, approximately 10 percent of the orthodontic patients demonstrated a more significant amount of loss of attachment and marginal alveolar bone loss. It should be noted that the cases studied involved severe malocclusions requiring extensive tooth movement.

In a longitudinal study by Alstad and Zachrisson (1979), conducted on thirty-eight adolescent patients where the Class I and Class II malocclusions had been treated with premolar extractions and results compared to a similar group of subjects with almost ideal occlusions, no difference was found in the loss of periodontal attachment up to 5 months after treatment. The orthodontic patients, however, did participate in an oral hygiene program during treatment.

Similarly, Kloehn and Pfeifer (1974) evaluated the gingival health and periodontal and alveolar bone support in fifty consecutively treated orthodontic extraction and nonextraction adolescent patients during and up to 4 months after treatment. In addition to noting a marked decrease in the hyperplastic gingivitis within 48 hours after the conclusion of treatment, their findings indicated that orthodontic treatment did not cause irreversible periodontal destruction.

Trossello and Gianelly (1979) also reported only minor differences in the health of the periodontal tissues and alveolar bone in a group of thirty female patients between 18 and 25 years of age at least 2 years after orthodontic treatment, as compared to a similar group of subjects who have never received orthodontic therapy.

Sadowsky and BeGole (1981) evaluated the periodontal health of a group of ninety-six patients who had received comprehensive fixed-appliance orthodontic treatment during adolescence. Comparisons were made with a group of 103 adults who were similar with regard to race, sex, age, socio-economic status, dental awareness, and oral hygiene status but had malocclusions that had not been orthodontically treated. There were no statistically significant differences in the general prevalence of periodontal disease between the two groups. However, more detailed analysis revealed that the orthodontic group had a greater prevalence of mild to moderate periodontal disease in the maxillary posterior and mandibular anterior regions of the mouth, as compared to the control group. The results suggested that orthodontic treatment in adolescence is not a major factor in determining the long-term periodontal health status. No significant amount of either damage or benefit to the periodontal structures could be directly attributed to orthodontic therapy. Conversely, the lack of orthodontic therapy in adolescence does not appear to influence subsequent development or non-development of periodontal disease in adults.

Davies *et al* (1991) evaluated the relationship between orthodontic treatment and subsequent periodontal health. Data from 417 children who were classified at baseline as having significant occlusal variations and who were present at the follow-up examination 3 years later were selected from an original group of 1015. One hundred and fourteen of these children received orthodontic treatment over this time period and provided two groups of children for comparison in this study. Plaque indices, bleeding indices, and degree of dental irregularity were recorded for each incisor and canine tooth. There were significant reductions in the plaque and gingivitis scores on all tooth surfaces between the baseline and 3 year examination in the two groups of children. The children who had received orthodontic treatment had the greater reduction, but this appeared to be more related to behavioural factors than to improved tooth alignment.

Orthodontic treatment, however, has been indicted for producing a large amount of periodontal disease by Pritchard (1975), who reported a study of 100 consecutive former orthodontic patients treated with four premolar extractions, who were referred to him for periodontal treatment. He did acknowledge the bias of his sample but succeeded in alerting orthodontists to potential periodontally hazardous situations during and after orthodontic treatment.

Dorfman (1978) studied the mucogingival changes resulting from mandibular incisor tooth movements in 1150 completed orthodontic cases. He found that a small percentage of cases (1.3 percent) showed a decrease in width of keratinised gingiva. These were statistically correlated with the magnitude and direction of tooth movement.

From the discussion it can be concluded that there is no direct relationship between orthodontic treatment and long-term periodontal disease. However, maintenance of periodontal health during treatment will lead to a better long-term result. The relationship between dental caries and orthodontics will now be discussed.

2.3 Dental caries and orthodontic treatment

There is general agreement that enamel caries begins beneath dental plaque (Shafer, Hine and Levy, 1984). Dental caries is one of the most common diseases of humans (Regezi and Sciubba, 1989). Dental caries may be defined as a bacterial disease of the calcified tissues of the teeth, characterised by demineralisation of the inorganic and destruction of the organic substances of the tooth (Wilkins, 1989; Soares and Southam, 1993).

2.3.1 Aetiology

Various theories for the aetiology of dental caries have been proposed, but there is now overwhelming support for the acidogenic theory. This theory, which has remained virtually unchanged since first postulated by Miller in 1889, proposes that acid formed from the fermentation of dietary carbohydrates by oral bacteria leads to progressive decalcification of the tooth substance with a subsequent disintegration of the organic matrix. Experiments with germ-free animals have shown that bacteria are essential for the development of dental caries. Dietary sugars diffuse rapidly through plaque where they are converted to acids (mainly lactic acid, but also acetic and propionic acids) by bacterial metabolism. The pH of the plaque may fall by as much as 2 units within 10 minutes after the ingestion of sugar. Some 30 to 60 minutes later, the pH of the plaque slowly rises to its original figure, due to the diffusion of the sugar and some of the acid out of the plaque, and the diffusion into the plaque of buffered saliva. At a critical pH, usually about 5.5, mineral ions are liberated from the hydroxy-apatite crystals of the surface enamel and diffuse into the plaque. Around a neutral pH the plaque is supersaturated with mineral ions because of the extra ions from the enamel and some of the excess ions in the plaque may be redeposited on the enamel crystal surfaces. There is, therefore, a see-sawing of ions across the plaque-enamel interface as the chemical environment within the plaque changes. Repeated acidic episodes, however, lead to an overall demineralisation and the initiation of enamel caries (Soares and Southam, 1993).

2.3.2 Clinical appearance of demineralisation

Clinically, dental caries may be classified as pit or fissure caries and caries of smooth surfaces. The earliest evidence of disease is a chalky-white etch on an otherwise translucent tooth enamel surface. Measured by micro-hardness testing, this altered enamel is softer than sound enamel. Scanning electron microscopy (SEM) presents a tooth surface covered with a multitude of tiny pits, resembling a honeycomb. Transmission electron microscopy at right angles to the surface reveals that the mineral crystallite density is reduced not only on the surface, but also to an even greater extent immediately beneath the surface (Regezi and Sciubba, 1989).

2.3.3 Microstructural changes with demineralisation

Initial decalcification assaults the enamel along its surface, dissolving individual hydroxy-apatite crystallites. Thinning and shortening of the individual crystallites is thus the initial evidence of decalcification. With time, acid dissolves crystallites to create micro-cavities. If the process continues, the micro-cavities enlarge and coalesce laterally across adjacent rods to form tunnels or interconnecting channels. The surface layer of enamel remains relatively intact until it is almost completely undermined.

The critical stage at which reversal of a lesion is no longer possible is believed to be the point at which the amount of crystallites removed compromises the integrity of the structural protein matrix (Regezi and Sciubba, 1989).

2.3.4 Orthodontic Patients

An increased cariogenic challenge is formed around orthodontic brackets and underneath bands. Early carious lesions in the enamel are observed clinically as a white opaque spot. The area is slightly softer than the surrounding sound enamel. The white is caused by an optical phenomenon and increases in whiteness when dried by air (Ogaard, Rolla and Arends, 1988; Ogaard, 1989).

The presence of clinically detectable areas of enamel demineralisation following the removal of orthodontic appliances is well recognised. The white spot lesion is considered to be a precursor of enamel caries and in orthodontics has been attributed to prolonged accumulation and retention of bacterial plaque on the enamel surface adjacent to the appliance. Favoured sites for such accumulation are around the cervical margins of the teeth, under the bands in areas where the cementing medium has washed out, on the resin surfaces adjacent to bonded attachments and at the junction of the bonding resin and the etched enamel (O'Reily and Featherstone, 1987).

Lesions that develop on the facial surfaces on both anterior and posterior teeth represent an unaesthetic side effect of orthodontic treatment that may counteract the beneficial results of the treatment as such (Ogaard, *et al* 1988).

The prevalence reported among patients ranged from 2 to 96 percent. This large variation is due to the variety of methods used to assess and score the presence of decalcification, whether idiopathic enamel lucencies were included or excluded, and the use or otherwise of a fluoride regime during treatment.

The distribution of affected teeth has been studied by several workers. Gorelick, Geiger and Gwinnett (1982) found maxillary incisors and mandibular first molars to be the teeth with the highest prevalence. Mizrahi (1983) found maxillary incisors and first molars to be most commonly affected. He also reported that the enamel opacities were found particularly on the cervical and middle thirds of the vestibular surfaces of affected teeth. Ogaard (1989) found the first permanent molars in both arches to have the highest prevalence. No difference was found between boys and girls and left and right sides. In contrast, Geiger *et al* (1988) reported that lesions occurred most frequently on maxillary lateral incisors and canines and on mandibular premolars. According to Årtun and Brobakken (1986) white spot lesions are particularly evident in the gingival enamel parts.

Various experimental techniques like microradiography, polarised microscopy, microhardness, and electron microscopy have been used to explore the characteristics of enamel demineralisation (Ogaard *et al*, 1988).

O'Reilly and Featherstone (1987) found that demineralisation occurs immediately adjacent to orthodontic appliances after only 1 month, even with the daily use of a sodium fluoride dentifrice. The demineralisation was as a result of plaque activity, not the initial acid etching before bonding. Up to 15% mineral loss, both occlusal to and cervical to orthodontic brackets was seen in patients. This loss was localised to an area 50-75μm beyond the periphery of the bracket base. The rapidity of the demineralisation was striking. It must be emphasised that this demineralisation could not be observed clinically. This would suggest that considerable mineral loss can occur without being observed by the clinician and clearly illustrates the importance of early and constant preventive therapy if demineralisation is not to continue.

The observation supported the work of Diedrich (1981) who used a SEM and reported that even though bonded teeth apparently had a normal enamel translucency, there was a physical lack of mineral in treated areas.

Ogaard *et al* (1988) used specially designed orthodontic bands for plaque accumulation which were attached to premolars scheduled to be extracted as part of an orthodontic treatment. Both microradiographic and SEM examinations showed surface softening of the enamel. Visible white spots were seen within 4 weeks in the absence of fluoride supplementation, the period of one orthodontic appointment to the next. Careful inspection of the orthodontic bands and brackets should therefore be carried out at every visit and preventative fluoride programs should be instituted. The clinical significance of the present study is that enamel demineralisation associated with fixed orthodontic therapy is an extremely rapid process caused by a high and continuous cariogenic challenge in the plaque developed around brackets and underneath ill-fitting bands. Gorelick *et al* (1982) showed that 50% of the subjects experienced an increase in the number of white spot lesions during treatment with fixed orthodontic appliances when no preventive fluoride program was used.

Generally, as the proportion of tooth surface covered by an orthodontic bracket increases, the more difficult it becomes for the patient to effectively clean the remaining uncovered enamel. However, this does not mean that using bands, rather than bonded attachments is more likely to result in decalcification. In practice, a well cemented band appears to be protective of the tooth surface it covers, although should the cement lute fail, extensive demineralisation can occur if the band is left for a lengthy time (Mitchell, 1992; Ogaard *et al*, 1988). Gorelick *et al* (1982) found no difference in the prevalence of white spot lesions in bonded or banded teeth. However, the site of plaque accumulation does differ between bonds and bands, with the latter favouring the development of plaque around the gingival margin with an increase in the potential loss of periodontal support (Cianco, 1988; Alexander, 1991).

From the above discussion it is evident that demineralisation and subsequent dental caries formation in patients undergoing orthodontic treatment will lead to irreversible damage. It is of great importance that patients reduce the level of plaque and consequently the level of dental caries to achieve an optimal orthodontic result.

2.4 Development of periodontal indices

Dental epidemiology with all its index systems is a fairly young science (Ainamo and Ainamo, 1978). Researchers in many fields have become increasingly aware of measurement error in the clinical examination. Also, comparison of data from various sources needs universal index systems. Consequently, calibrations systems together with index systems have been formulated. Klein and Palmer (1938) first introduced the Decayed, Missing and Filled (DMF) index. This index is only a caries index and was included in this heading as it was the first index developed for measuring a dental condition for epidemiological purposes.

Specific periodontal index systems were developed over the past four decades. Schour and Massler (1947) described the Papillae-Margin-Attached Gingival Index (PMA). This index assesses the gingival condition of patients. The quantitative evaluation rested on the assumption that the gingivae respond to local or systemic disturbances most frequently by varying degrees of inflammation. The severity of the inflammation was graded numerically according to increasing intensity and extent of the disease. This index has some broad applications to surveys and clinical trials. It has also served as the basis for subsequent indices.

Parfitt (1957), among others, modified the PMA Index which he used extensively in periodontal epidemiology, especially with children. The main feature of the modification was the addition of a severity rating to the diagnosis of the presence of gingival inflammation. The condition of each interdental papilla, margin or attached mucosa on the buccal or lingual surface of each tooth was observed and recorded.

Such a clinical assessment is dependent upon the judgement of an observer but the grades are well defined, are well recognised in clinical practice and differ markedly from one another. Even the grades of detectable and mild gingivitis are, in most instances, well defined. However, as in all clinical assessments borderline cases occur and reproducibility of findings of the same observer or between different observers is not perfect.

In this method the presence of inflammation and the severity of inflammation in each gingival area are recorded separately and the accuracy of one observation is not submerged beneath the inaccuracy of the others; the advantages of each clinical assessment are thus retained.

In the late 1950's the World Health Organisation (WHO) sponsored a series of epidemiological studies in the Far East. The Periodontal Index (Russel, 1956), the Periodontal Disease Index (Ramfjord, 1959) and finally the Oral Hygiene Index (Greene and Vermillion, 1960) were formulated to allow for rapid examination of large populations with advanced periodontal involvement.

While these indices proved too crude for use in experimental studies and short term clinical trials new indices had to be formulated.

Löe and Silness formulated the Gingival Index (GI) (Löe, 1967) to determine the different degrees of inflammation within the region of the marginal gingiva. Silness and Löe (Löe,1967) then defined the Plaque Index (PI) to determine the thickness of plaque at the gingival margin, instead of the coronal extension suggested by Greene and Vermillion (1960). These two new indices proved to be of great value and made it possible to demonstrate the indisputable correlation between plaque formation and the initiation of gingivitis.

In the early 1970's the WHO recognised that there was dissatisfaction with the measurement of periodontal disease and treatment requirements in populations. Johansen, Gjermo and Bellini (1973) proposed the Periodontal Treatment Need System (PTNS). This system expressed treatment needs according to clinical findings, type of therapy and the corresponding time necessary to deliver the treatment. This index assesses the gingival recession, gingivitis, amount of calculus and pocket depth.

Following on the PTNS, the Community Periodontal Index of Treatment Needs (CPITN) was developed (Ainamo and Ainamo, 1978). The CPITN evaluates both periodontal status and the periodontal treatment needs in a population and estimates the resources required in terms of time units and personnel (Ainamo *et al*, 1982).

The most common use for CPITN, to date, has been in identifying prevalence and severity of periodontal conditions with respect to treatment needs. CPITN has also been widely used in private practice. Dental associations already recommending the utilisation of CPITN by their practitioners include Finland, New Zealand, Australia, Japan, United Kingdom (UK) and regions in Norway; several other countries are currently giving serious consideration to this matter (Cutress, Ainamo and Sardo-Infirri, 1987). In the UK a national plan for "Self assessment for gum health" is being promoted and dental practitioners encouraged to participate in a programme of assessing periodontal needs using CPITN procedure. In New Zealand, CPITN is included in the dental undergraduate teaching curriculum. Also, a periodontal awareness campaign initiated to reduce gingivitis and periodontitis called for the introduction of CPITN into general dental practice in New Zealand (Croxson, 1984). In Finland, the Public Dental Health Service has adopted the use of the CPITN for all children aged seven to nineteen years since January 1985. All adults attending the Public Health Centres are also scored for CPITN. Used with common sense and an understanding of periodontal disease, the CPITN procedure provides the epidemiologist and the practitioner with a practical means of assessing periodontal treatment needs.

Recently, Bearn *et al* (1996) developed the Index of Oral Cleanliness (IOC). The index was designed from studies of previously published reports on plaque distribution. Lilienthal, Amerena and Gregory (1965), Löe *et al* (1965) and Alexander (1971) all found similar patterns of plaque distribution. Plaque deposits increased from anterior to posterior in the mouth, and were greater in the mandibular than maxillary dentition. Löe *et al* (1965) and Cumming and Löe (1973) also found that plaque deposits were greater on lingual surfaces of the teeth compared with buccal surfaces. The heaviest plaque deposits were recorded interproximally, increasing from anterior to posterior. Lang, Cumming and Löe (1973) confirmed these patterns of distribution and reported a correlation with toothbrushing frequency. These reports suggested the potential of an index based on an assessment of plaque distribution. Bearn *et al* (1996) validated the IOC in their study taking randomly selected adolescents. They recommend that this index be further validated in a population undergoing orthodontic treatment.

In the presence of standardised methods to evaluate progress of diseases, control of plaque and periodontal diseases may be assessed. Toothbrush comparisons will be discussed using these standardised evaluation methods.

2.5 Toothbrush Comparisons

In *The Toothbrush: Its Use and Abuse*, Hirshfeld (1939) states: "Correct and routine toothbrushing will soon iron out, so to speak, all the irregularities in, and restore normal colour and contour to, the gingivae .... Thus, since the toothbrush may so readily aid in the resolution of these incipient symptoms, its potentiality in their prevention is evident."

While toothbrushing continues to be the most widely used form of oral hygiene procedures, Fraudsen (1986) concluded that toothbrushing is far from satisfactory in controlling plaque. Toothbrushing clinical effectiveness is dependent on a number of factors, including toothbrush design, toothbrushing methods, time and frequency, and the evaluation methods. Demonstrating significant differences between toothbrushes is difficult because of the number of factors needing to be controlled.

Historically, manual toothbrush bristles had a hard texture since it was believed that this feature would result in cleaner teeth and healthier gingiva (Fraudsen, 1986). When reports began to surface in the second half of this century on the prevalence of both hard and soft tissue trauma caused by the long-term use of these hard-bristle brushes, toothbrush manufacturers began producing soft-textured brushes (Mintel and Crawford, 1992). This was accomplished by using thinner diameter bristles and by applying some degree of grinding or polishing to remove sharp burs on the cut end of the bristles. These soft brushes, together with the production of low abrasive toothpastes and better professional oral hygiene instruction on proper brushing techniques, have done much to reduce the incidence of dental tissue damage caused by daily toothbrushing.

In the field of toothbrush research, the advent of computer assisted design (CAD) has spurred the product development cycle exponentially (Mintel and Crawford, 1992). New realms of possibility are open to the researcher, and multiple outcomes can be realised for evaluation. The effect of this design tool has already been felt. In recent times the toothbrush category, for so long represented by variations on a flat-bristled theme, has undergone an unprecedented surge in bristle redesign activity. New manual toothbrushes, designed to heighten the impact of the toothbrushing regimen on oral health, have been introduced. These new designs have shown significant activity in laboratory studies of artificial plaque removal and interproximal access efficacy. (Yankell, Shi and Emling, 1992 and 1993;

Yankell *et al* 1993; Battista and Petrone, 1993, Yost, Miluszewski and Chen, 1994; Volpenheim *et al,* 1994)

A number of *in vitro* and *in vivo* studies have been carried out to compare various toothbrush designs. Some of these studies relevent to this study will be discussed and their outcomes evaluated.

2.5.1 Studies on Colgate Precision toothbrush

Yankell, Shi and Emling (1994) compared the Colgate Precision Compact soft texture toothbrush and the Oral-B 35 toothbrush using a laboratory device designed to simulate clinical toothbrushing motions and pressures. The toothbrushing time was sixty seconds for each vertical or horizontal toothbrushing sequence, for each of the three brushing weights tested (250, 500 or 750g).

Interproximal access efficacy (IAE) was determined by measuring the maximum width of the brushing stroke on pressure-sensitive paper placed around simulated anterior or posterior teeth. Twenty-four toothbrushes of each design were evaluated for each toothbrushing motion, tooth shape and toothbrushing weight. Using the vertical toothbrushing motion on anterior teeth, IAE means for the Colgate Precision Compact toothbrush were significantly higher ($p<0.001$) than the Oral-B 35 toothbrush at 250 and 750g of brushing weight. With vertical toothbrushing across posterior-shaped teeth, IAE values for the Colgate Precision Compact toothbrush were significantly higher ($p<0.001$) than the Oral-B 35 toothbrush at each of the 250, 500 and 750g brushing weights tested. With horizontal toothbrushing motions, the Colgate Precision Compact toothbrush had significantly higher ($p<0.001$) IAE means, compared to the Oral-B 35 toothbrush, on both anterior and posterior tooth shapes and at each of the brushing weights tested. When all factors tested were combined, the total IAE for the Colgate Precision Compact toothbrush was significantly superior ($p<0.001$) to the Oral-B 35 toothbrush, thus implying that the Colgate Precision toothbrush has a greater interproximal access efficacy. This may be significant when using the Colgate

Precision toothbrush in fixed orthodontic cases as greater access around brackets may lead to an increase efficiency of brushing.

Sharma *et al* (1994) evaluated the Colgate Total along with the New Improved Crest Complete, Reach Advance design and Oral-B Advantage. They reported that the mean plaque and gingivitis values were not significantly different at baseline between the four groups. Results from this three-month clinical study demonstrated a significant reduction ($p<0.0001$) in plaque levels and gingivitis for all of the four toothbrushes compared to baseline. At both six weeks and three months, mean gingivitis and plaque scores were significantly lower ($p<0.01$) in the Colgate Total group compared to the other three toothbrushes tested. When changes from six weeks to three months were statistically analysed, only the Colgate Total toothbrush significantly reduced ($p<0.001$) mean gingivitis scores.

In an earlier study Sharma *et al* (1992) evaluated and compared the clinical performance of three toothbrushes on plaque removal. This included the Colgate Precision, Oral-B 40 and Reach Full-Head soft toothbrushes. They concluded that the Colgate Precision toothbrush was significantly more effective ($p<0.01$) than both the Oral-B 40 and Reach Full-Head soft toothbrushes in reducing whole mouth plaque scores, as well as plaque at the gumline and at interproximal areas. The Oral-B 40 and Reach toothbrushes were not significantly different from each other with regard to plaque removal.

Deasy *et al* (1993) evaluated and compared the plaque removal performance of the complete designed Colgate Precision with that of two commercially available products, the Oral-B and Reach Full-head soft toothbrushes. Statistical analyses indicated that the Colgate Precision Full-head soft toothbrush removed significantly more plaque than either of the other two brushes.

Sing *et al* (1992) in a cross-over study to compare the ability to remove plaque of two toothbrushes, namely Colgate Precision and Oral-B 40, concluded that the

Colgate Precision toothbrush was significantly more effective in reducing whole mouth plaque scores, plaque scores at the gumline, and plaque scores at interproximal areas.

2.5.2 Studies on the Oral-B Advantage toothbrush

Grossman, Dembling and Walley (1994), compared the plaque removal and gingivitis reduction efficacy of Oral-B Advantage Plaque Remover to five manual toothbrushes. Two long-term studies were conducted. In Study 1, the Oral-B Advantage Plaque Remover was compared to the Crest Complete and Colgate Precision toothbrushes. In Study 2, the Oral-B Advantage Plaque Remover was compared to the Reach Advanced Design, Colgate Plus and Jordan Exact toothbrushes. The results of both studies were as follows: The Oral-B Advantage Plaque Remover was significantly more effective than the Crest Complete, Colgate Precision, Colgate Plus and Jordan Exact toothbrushes in whole mouth plaque removal ($p<0.05$), and vs all brushes tested in gingivitis reduction ($p<0.01$) and in reducing gingival bleeding ($p<0.001$).

Rawls *et al* (1993), compared the bristle end rounding of three commercially available toothbrushes under an electron microscope. The three toothbrushes were Oral-B P-35, Colgate Precision and Crest Complete toothbrushes. The results showed that the end-roundness fell in the order Oral-B P-35 more rounded than the Crest Complete, which in turn was more rounded than the Colgate Precision. Thus they concluded that the potential for harming dental tissues is less for the Oral-B P-35 toothbrush than for either the Colgate Precision or Crest Complete toothbrushes.

2.5.3 Studies on the Aquafresh toothbrush

Soparkar, Newman and De Paola (1991) compared the Aquafresh Flexsoft medium and firm bristle versions to a widely available, standard brush with soft bristles. Safety, as well as plaque and gingivitis were evaluated at baseline, two weeks, and six weeks. At termination, all brands were considered to be safe. After two weeks, the mean plaque scores for each of the four groups were reduced significantly, although a difference between the control group and the test groups could not be demonstrated. Between two and six weeks, the mean plaque scores for the test brushes levelled off while the corresponding score for the control brush increased significantly. The gingivitis scores showed a similar pattern. This pattern suggested a more favourable used acceptance for the test brushes, which was consistent with information provided by the subjects on a post-study questionnaire. Presumably, this phenomenon was associated with the unique design of the test brushes.

To conclude on the comparison of toothbrushes, Reardon *et al* (1993) compared the efficacy of the Oral-B P-35, Crest complete, Colgate Precision toothbrushes in four independent clinical studies. They found that in all four studies, there were no significant differences between any of the toothbrushes.

In a survey of dentists' personal preferences and recommendations for patients in Australia, Gortjamanos, Singh and Strangio (1992) reported that 79% of dentists surveyed received free samples, with Oral-B comprising 33% of all such samples, followed by Colgate (16%) and Tek (13%). Fifty-three per cent of dentists surveyed indicated they used all free samples received. Sixty-two per cent of dentists do not consider that different brushes differ significantly in their plaque-removing ability. Therefore, while an effective toothbrushing technique is important, selection of the correct toothbrush from the wide range available may not be critical.

2.6 Effectiveness of toothbrushing on oral hygiene during fixed orthodontic treatment

A number of studies have reported on the most effective way in reducing plaque deposits around orthodontic brackets.

Jackson (1991) reported that according to Rosendahl (1962), the first motor-driven toothbrush was displayed at the American Dental Association (ADA) convention in St Louis in 1938. Since its arrival, controversy over the relative effectiveness of electric brushing over manual brushing has continued. Many authors have reported superiority of the electric toothbrush in controlling different measures of oral health, while other studies conclude that there is no appreciable difference between the levels of oral hygiene that can be achieved with either device.

Boyd and Rose (1994) in their study investigated whether the rotary electric toothbrush would be more effective than conventional toothbrushing for maintaining periodontal health during fixed orthodontic treatment. The results of this 18-month study show that the Rota-dent can be more effective than conventional toothbrushing in maintaining the periodontal health of adolescents undergoing treatment with fixed orthodontic appliances. Scores for the Plaque Index, Gingival Index and bleeding tendency increased significantly for the control group during the study, but remained reasonably stable for the treatment group. Because gingival inflammation typically increases after fixed appliances are placed, these results suggest that the lack of increase in the treatment group scores occurred because the Rota-dent prevented gingival inflammation that would have occurred had it not been used. The results also show that the short, pointed brush tip of the Rota-dent effectively reduces interproximal plaque and prevents interproximal gingivitis.

A study was conducted to determine whether daily use of a rotary electric toothbrush (Rota-dent) and a 0.05% sodium fluoride (NaF) rinse would significantly reduce decalcification when compared with manual toothbrushing only (control group) or manual toothbrushing and daily use of a NaF rinse (rinse group). Boyd and Rose (1994) suggested that the twice daily use of the Rota-dent electric toothbrush with a standard fluoride toothpaste and once daily use of a 0.05% NaF rinse is more effective in preventing decalcification in adolescents during orthodontic treatment with fixed appliances than either conventional toothbrushing with a fluoride toothpaste, or similar toothbrushing and toothpaste with a once daily NaF rinse.

A number of recent studies have shown that there is no significant difference in oral hygiene when comparing manual to certain electric toothbrushes. Heintze *et al* (1996) evaluated the effectiveness of three different types of electric toothbrushes during active appliance therapy under home conditions: Interplak, Rota-dent and Braun Oral-B Plaque Remover. A manual technique, which included normal toothbrush, interdental brush, and dental floss, served as reference. The study concluded that the Rota-dent showed statistically significant lower plaque scores than the manual technique. For all the other toothbrushes, no differences were found in comparison to the manual technique. For plaque indices of specific sites, statistical analysis revealed all electric toothbrushes to be equal to the manual technique. No differences in gingival bleeding indices were found after 4 weeks with either toothbrush. Patients with poor oral hygiene who used Rota-dent and Braun Oral-B Plaque Remover OD5 had statistically significant lower plaque scores compared to the manual technique ($p<0.01$; $p>0.05$ respectively); for patients with good oral hygiene, these differences were neutralised. It may be concluded that patients with poor oral hygiene may benefit from electric toothbrushes, especially because plaque removal can be achieved easier and faster.

Trimpeneers *et al* (1997) compared the effectiveness of three different types of electric toothbrushes, i.e. Interplak, Philips and Rota-dent, with a manual multitufted toothbrush (Blend-a-Med), in removing supragingival plaque and in preventing the development of gingivitis in adolescent patients with fixed orthodontic appliances. The results demonstrated that for all parameters the manual toothbrush was the most effective. Of the three electric toothbrushes tested, the Philips toothbrush seemed to give slightly better results than the Interplak toothbrush, whereas Rota-dent gave results inferior to all others.

Kiliçoglu *et al* (1997) investigated whether orthodontic toothbrushes were superior to classical toothbrushes in the elimination of microbial dental plaque on teeth and brackets and in the maintenance of periodontal tissue health in patients with fixed appliances, ages 12 to 22 years. Twenty patients undergoing orthodontic treatment with fixed appliances and brushing with the Bass technique were included in the study. Ten patients used the Oral B Orthodontic type toothbrushes, whereas the remaining 10 patients used the Oral B Plus 35 type toothbrushes. The Quigley-Hein plaque index, bonded bracket index, sulcus bleeding index, and periodontal pocket depth measurements were conducted at the beginning of the study as well as a month later. No statistically significant difference was found for plaque, sulcus bleeding, and periodontal pocket depth between the Oral-B Orthodontic and Plus 35 groups when the pre- and post-investigatory measurements for the vestibular and proximal surfaces of upper and lower teeth were compared. This short-term study concluded that the Orthodontic type toothbrush is not superior to the Plus 35-type toothbrush. The results should be interpreted with caution as a very small sample size was used and a cross-over design was not used in this study.

Heasman *et al* (1998) compared the new Dental Logic HP550 Philips electric toothbrush to the Braun Oral-B Plaque Remover with a dedicated orthodontic brush head and to the manual dedicated orthodontic toothbrush. Their results showed that there was no significant effect on visible plaque or gingival bleeding indices with any toothbrush for any tooth surface. They suggested that the new HP550 is equally effective as the specifically designed orthodontic toothbrushes in removing plaque from patients with fixed orthodontic appliances.

From the literature reviewed it is evident that there are conflicting reports on the effectiveness of electric brushing over manual brushing and also between various manual toothbrushes.

2.7 Effective oral hygiene for orthodontic patients

Fixed appliances make plaque removal more difficult because of the increase in surfaces and the inaccessibility of some areas. Orthodontists must emphasise patient education, motivation, and regular monitoring to ensure effective disease prevention.

There are two main factors that orthodontists should consider in deciding which oral hygiene adjuncts to prescribe: specific patient needs (susceptibility to disease, oral condition) and individual characteristics (aptitude, dexterity, lifestyle). Expectations of ideal home care may need to be tailored to the particular patient.

Some of the available oral hygiene adjuncts will be discussed.

2.7.1 Toothbrushes

A manual toothbrush with soft, rounded nylon bristles is effective when used gingival to the brackets and archwires, with the bristles angled toward the gingival margin. A scrub or Bass technique, using horizontal, short strokes and moderate pressure, yields the best results (Zachrisson, 1974). Patients should also be advised to modify their brushing habits after removal of their orthodontic appliances, since brushing which is too intense can cause damage to teeth and gingivae.

A single-tufted brush (End-Tuft Brush) can be a useful supplement because it adapts around and under loops, springs, ligatures, furcations, recessions, and terminal molars. It is particularly appropriate for periodontally involved patients, but it requires a greater degree of compliance. A study by Gjermo and Flotra (1970) showed a 50 percent reduction in interproximal plaque among non-orthodontic patients using a single-tufted brush combined with floss or an interdental stick.

Electric toothbrushes have been found to be effective, however, there have been studies that show conflicting results among orthodontic patients (Heintze *et al*, 1996; Trimpeneers *et al*, 1997).

2.7.2 Interdental Adjuncts

For patients with wide embrasures, a variety of interdental brushes are available including disposable travel brushes, brushes with wire handles and longer heads, and brushes with interchangeable heads of different shapes. Interdental brushes can

be used for interproximal application of fluoride rinses or gels, and orthodontic patients can hold them vertically to brush under archwires. In a study of non-orthodontic patients (Gjermo and Flotra, 1970) interdental brushes were rated the most effective interproximal cleaner for removal of food debris and plaque.
Dental floss is useful when tight contacts prevent access with an interdental brush. A floss threader can be guided under archwires and a wrap technique with a gentle "shoeshine" motion will avoid gingival trauma. Waxed and unwaxed flosses are equally effective in plaque removal. Flavoured floss is often popular with patients.

Super Floss is a threader that holds a continuous strand of nylon filament and floss. The threader can be used interdentally where space is adequate, or under archwires with the wrap technique. Wong and Wade (1985) found Super Floss slightly more effective than waxed floss in removing interproximal plaque, possibly due to the nylon filament.

It should be noted that flossing around orthodontic appliances is difficult and tedious, and that either regular floss or Super Floss may present problems with patient compliance.

2.7.3 Fluoride

Patients with fixed orthodontic appliances have higher levels of *S mutans*, perhaps because of elevated plaque carbohydrate levels and residual debris, with a consequent increase in bacterial acidity (Chatterjee and Kleinberg, 1979). Bonded brackets promote decalcification by increasing the colonisation of *S mutans* on adjacent enamel. Daily use of a fluoride gel or rinse will alleviate this increased susceptibility to demineralisation.

Despite controversy over the most appropriate agents and methods of delivery, there is general agreement that topical fluoride applications are beneficial in caries prevention. Consistent home use under professional supervision produces the best results. However, constant monitoring and regular professional fluoride treatments are necessary, because it is not uncommon to find patient compliance as low as 50 percent (Geiger *et al*, 1988).

2.7.4 Oral Irrigators

Oral irrigators are effective for orthodontic patients in conjunction with toothbrushes and interdental adjuncts. When used with a chemotherapeutic agent, oral irrigators have been shown to reduce plaque and gingivitis in non-orthodontic patients (Aziz-Gandour and Newman, 1986; Agerbeck, Melsen and Rolla, 1975).

For patients whose plaque control is inadequate, daily application of a diluted chlorhexidine solution can be prescribed. The lowest effective concentration is recommended, since patient compliance can be reduced by the unpleasant taste, staining property, and high cost of chlorhexidine. Application of chlorhexidine should be at least 60 minutes before fluoride use to avoid an interaction that would result in lessened effectiveness of both agents.

The various oral hygiene adjuncts as well as advantages and disadvantages of each are summarised in Table 1.

2.8 Summary

From the discussion presented in this chapter, it is evident that effective plaque control is the primary factor in reducing periodontal disease and caries in orthodontic patients. Through various studies reported in the literature, a wide range of toothbrushes have been shown to be effective in maintaining oral health. Apart from toothbrushes, other oral hygiene adjuncts available to assist a patient with fixed orthodontic appliances to maintain good oral hygiene have been discussed in this chapter.

Chapter 3 discusses the materials and methods used in the project including selection of the sample, evaluation criteria and study design.

Table 1: Available oral hygiene adjuncts together with recommendations for use by orthodontic patients.

ADJUNCT	USES	ADVANTAGES	DISADVANTAGES
Manual toothbrush	Buccal, lingual Surfaces; scrub Bass techniques	Good for buccal, lingual surfaces	Hand action is inconsistent
Orthodontic toothbrush	Tooth surfaces above and below brackets; scrub, Bass techniques	Adapts around archwires and brackets	Usable only for archwires, brackets
End-tuft toothbrush	Supplement to manual brushing; furcations; around loops, ligatures; terminal molars; recessions	Small head provides access; flat or tapered	Time-consuming; extra adjunct
Electric toothbrush	Angled toward gingival margin	Small head; Economical	Does not adapt well around brackets
Rota-dent	Angled at 90° to gingival margin	Small heads; three brush types	Cost
Interplak	Horizontal – upper row at gingival margin, lower under brackets	Tufts rotate independently	Large head; cost; may be abrasive
Interdental toothbrush	Floss substitute in diastemas, wide spaces; fluoride application; held vertically between brackets	Many sizes; accommodates anatomical variations	Useful only for wide embrasures
Floss	Tight contacts; used with floss threader	Flavours; waxed or unwaxed	Tedious; requires dexterity; difficult with brackets
Super Floss	Narrow diastemas, tight contacts	Threader included; easy to insert	Tedious; requires dexterity; may be abrasive
Oral Irrigator	Supplement to brushes, interdental adjuncts; used with chlorhexidine	Reduces food debris, plaque, gingivitis	Unpleasant taste; staining; cost; extra adjunct; compliance
Fluoride	Daily brush-on gel or rinse; in-office treatment	Prevents decay, demineralisation	Taste; patient compliance

Reproduced from Berglund and Small (1990)

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

A cross-over longitudinal study design was used for this study involving subjects undergoing fixed orthodontic treatment. Ethical approval by the Research Committee of the University of Pretoria (Dental School) was granted. This Chapter deals with all aspects of the study including selection of the sample, evaluation criteria, study design and data recording and analysis.

3.2 Selection of the sample

After permission was obtained from the parent or patient, fifty subjects undergoing Edgewise fixed orthodontic therapy at the Department of Orthodontics, Faculty of Dentistry, University of Pretoria, were randomly selected to take part in the study. Only patients who had full-arch fixed appliances with buccally bonded attachments on both the upper and lower jaw were selected. Exclusion criteria included a history of early onset of periodontal disease, a physical handicap that restricted free movement of hands or fingers and patients that would have surgery as part of their treatment. The ages of the subjects ranged between 11 and 27 years. During the course of the study 4 subjects withdrew due to lack of compliance. All patients were treated by either of 3 resident orthodontic registrars in the Department of Orthodontics.

3.3 Toothbrushes and toothpaste

Colgate Maximum Cavity Protection toothpaste, sponsored by Colgate-Palmolive South Africa, was given to all the subjects for the duration of the experimental period in order to prevent any other variable that may be introduced by using different toothpastes.

The toothbrushes evaluated were (Figure 1):

1. Orthodontic Oral-B toothbrush (TB1) – Gillett (SA)
2. Oral-B Advantage Controlgrip 30 (TB2) – Gillett (SA)
3. Colgate Precision – Medium (TB3) – Colgate Palmolive (SA)
4. Aquafresh – Interdental (TB4) – SmithKline Beecham

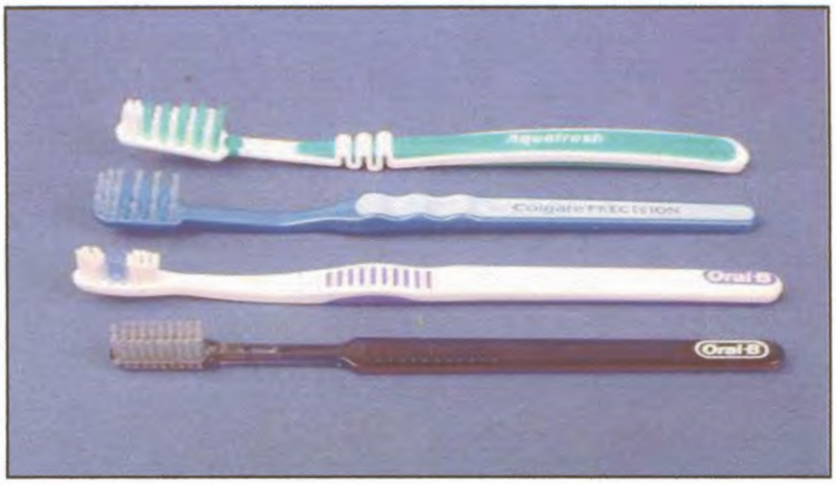

Figure 1: Toothbrushes evaluated

3.4 Instrumentation

The examinations were performed under a mixture of artificial and dental light using a plane mouth mirror and the WHO 6-5-20 periodontal probe (Figure 2).

Figure 2: Instruments used

The WHO 6-5-20 periodontal probe has been previously described (Emslie, 1980; Ainamo *et al* 1982) and is currently manufactured by at least three companies (J Manita Co., Tokyo, Japan; LM Dental, Turku, Finland; Hu-Friedy, USA), The PCP-115B probe manufactured by Hu-Friedy USA was used in this study.

The important characteristics of the WHO probe are its ball end and the colour-coded area between 3.5mm and 5.5mm (Figure 3). The spherical tip greatly assists in the detection of subgingival calculus or other roughness of the tooth surface and also facilitates assessment of the apical extent of the pocket by reducing the risk of over-measurement. The colour-coded area allows direct reading of pocket depths of 3mm or less, of pockets which are 4mm or 5mm deep, and of pockets which are 6mm or deeper.

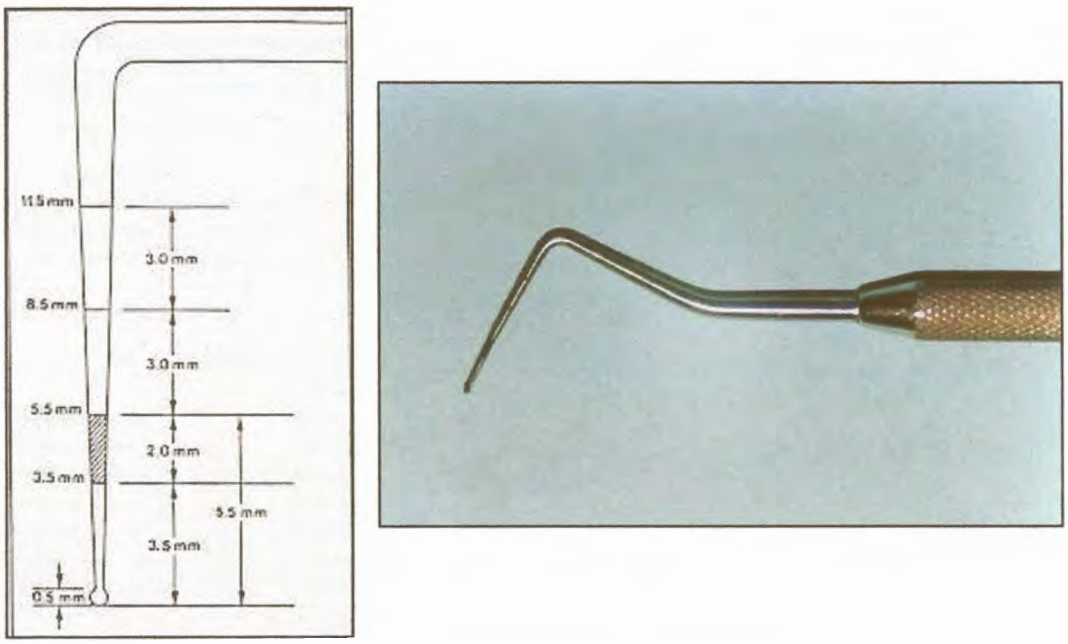

Figure 3: The WHO probe

The examination is done by gently inserting the probe into the pocket until resistance is felt. The pressure recommended in probing is no more than 25g (Ainamo *et al*, 1982). In practice this is equivalent to that needed to insert the probe under a finger nail without causing pain. The probe is then run along the gingival crevice to detect plaque and to elicit bleeding if inflammation is present.

3.5 Evaluation criteria

The effectiveness of the 4 toothbrushes in plaque control was evaluated by means of a well established plaque and gingival index as well as the newly reported Index of Oral Cleanliness (Bearn *et al*, 1996).

3.5.1 Plaque Index

The Plaque Index (PI) of Silness and Löe (Löe, 1967) was used to determine the amount of plaque on the tooth surface. The presence of plaque was detected using the WHO probe which was run in the gingival crevice from the distal to medial papillae both lingually and buccally. The mesiofacial, buccal, distobuccal and lingual surface of six teeth (16, 22, 24, 36, 42, 44) were scored as follows:

CODE	CATEGORY	CRITERIA
0	No plaque in the gingival area	This score is given when the gingival area of the tooth surface is literally free of plaque. The surface is tested by running a pointed probe across the tooth surface at the entrance of the gingival crevice, and if no soft matter adheres to the point of the probe, the area is considered clean.
1	A film of plaque adhering to the free gingival margin and adjacent area of the tooth.	This score is given when no plaque can be observed in situ by the unaided eye, but when the plaque is made visible on the point of the probe after this has been moved across the tooth surface at the entrance of the gingival crevice.
2	Moderate accumulation of soft deposits within gingival pocket on the gingival margin and/or adjacent tooth surface, which can be seen by the naked eye.	This score is given when the gingival area is covered with a thin to moderately thick layer of plaque. The deposit is visible with the naked eye.
3	Abundance of soft matter within the gingival pocket and/or on the gingival margin and adjacent tooth surface.	Heavy accumulation of soft matter, the thickness of which fills out the nicks formed by the gingival margin and the tooth surface. The interdental area is filled with soft debris.

Each of the four areas of the gingiva surrounding each tooth is given a score ranging from 0 to 3. The scores from the four areas are added and divided by four to give the PI score for each tooth. By adding the scores of each tooth and dividing by the number of teeth examined, the PI score for each individual is obtained. Scoring according to this criteria required light, drying of the teeth and gingiva, and use of a mirror and WHO probe.

3.5.2 Gingival Index

The Gingival Index (GI) of Löe and Silness (Löe, 1967) was used for the assessment of the gingival condition which clearly distinguished between the quality of the gingiva (the severity of the lesion) and the location (quantity) in four areas namely buccal, mesial, distal and lingual which make up the total circumference of the marginal gingiva. A blunt instrument, such as a periodontal probe was used to assess the qualitative changes in the gingival soft tissue. Each of the four gingival areas of the tooth are given a score ranging from 0 to 3. The scores for the four areas of the tooth are added and divided by four to give the GI for the tooth. The GI scores obtained from each tooth is added together and the total divided by the number of teeth examined to give the GI score for the individual. For this study only positive or negative bleeding scores were recorded (codes 0 and 2). The mesiobuccal, buccal, distobuccal and lingual surfaces of the same teeth used for the PI were scored. As with the PI, the GI for each individual was obtained using the following criteria:

CODE	CATEGORY	CRITERIA
0	Absence of inflammation	Gingivae are pale pink to pink No bleeding on probing
2	Moderate inflammation	Moderate glazing, redness, oedema and hypertrophy. Bleeding on probing.

3.5.3 Index of Oral Cleanliness

Bearn *et al* (1996) reported that the Index of Oral Cleanliness (IOC) provides a reliable, rapid and quantitative method of scoring oral hygiene. However, the IOC has not yet been validated in patients wearing either fixed or removable appliances. The recordings of this index was done as follows:

CODE	CRITERIA
4	facial surface plaque on two or more adjacent upper anterior 321|123 teeth;
3	facial surface plaque on two or more adjacent posterior teeth;
2	lingual surface plaque on two or more adjacent posterior teeth;
1	visible plaque deposits on one or more non-adjacent tooth surfaces;
0	no visible plaque

The teeth were dried with air and the examination was started on the facial surfaces of the upper anterior teeth, progressing as necessary to buccal surfaces of posterior teeth, lingual surfaces of posterior and then all other tooth surfaces, without the use of disclosing solution or probes. The presence of calculus was ignored and only the highest applicable score was recorded for the dentition.

3.6 Examination Procedure and Calibration

All examinations were carried out in the Department of Orthodontics at the University of Pretoria Oral and Dental Hospital. The examinations were done randomly by the author, an orthodontic registrar and a qualified oral hygienist. The oral hygiene students together with other administrative personnel assisted in recording of the results.

The examiners were trained and calibrated for PI, GI and IOC by an oral epidemiologist (gold standard). The calibration of the two examiners involved examination of 10 patients and calculating the correlation amongst them and the gold standard. A correlation of more than 80% was achieved by both examiners.

Prior to the commencement of the study, the examiners and recording personnel were trained in periodontal recording skills. The data form was explained to all the team members prior to calibration. Personal details were recorded for each patient at their first examination and only their unique identifier at subsequent visits. The patients were seated in the dental chair. Examinations were done from behind under the dental light using a plain mouth mirror and the WHO periodontal probe.

3.7 Study design

3.7.1 Oral Hygiene Instructions

Instructions on oral hygiene were given by oral hygiene students by means of charts and models to all the patients prior to the use of the toothbrushes. Oral hygiene students were assessed before each experimentation period for uniformity of instructions.

The oral hygiene treatment was co-ordinated by the Oral Hygiene Division, Faculty of Dentistry, University of Pretoria. Patients received their scaling and polishing and oral hygiene instructions from the oral hygiene students and were supervised and checked by the oral hygiene staff.

Each patient was provided with Colgate toothpaste together with the appropriate toothbrush. The patients were instructed to brush using the scrub technique and to floss. Each patient was given the same oral hygiene instructions both before and after use of the toothbrush.

3.7.2 Experimental design

A cross-over longitudinal study design was used. The names of the 45 pupils were arranged in descending order and divided into 4 groups. A random choice was made for the first toothbrush allocation (TB1, TB2, TB3 and TB4) for each group after which allocation alternated between groups A, B, C or D ensuring that each patient used all of the 4 experimental toothbrushes (Figure 4).

The cross-over design was as follows:

Week 0:

All participants are given a scaling and polishing together with oral hygiene instructions.

Week 4:

Baseline recordings of PI, GI and IOC

Group A	Group B	Group C	Group D
TB1	TB2	TB3	TB4

Use toothbrush for 2 weeks

Week 6:

Recordings of PI, GI and IOC after which participants will be given a scaling and polishing together with oral hygiene instructions.

Week 10:

Recordings of PI, GI and IOC

Group A	Group B	Group C	Group D
TB4	TB1	TB2	TB3

Use toothbrush for 2 weeks

Week 12:

Recordings of PI, GI and IOC after which participants will be given a scaling and polishing together with oral hygiene instructions.

Week 16:

Recordings of PI, GI and IOC

Group A	Group B	Group C	Group D
TB3	TB4	TB1	TB2

Use toothbrush for 2 weeks

Week 18:

Recordings of PI, GI and IOC after which participants will be given a scaling and polishing together with oral hygiene instructions.

Week 22:

Recordings of PI, GI and IOC

Group A	Group B	Group C	Group D
TB2	TB3	TB4	TB1

Used toothbrush for 2 weeks

Week 24:

Recordings of PI, GI and IOC after which participants will be given a scaling and polishing together with oral hygiene instructions.

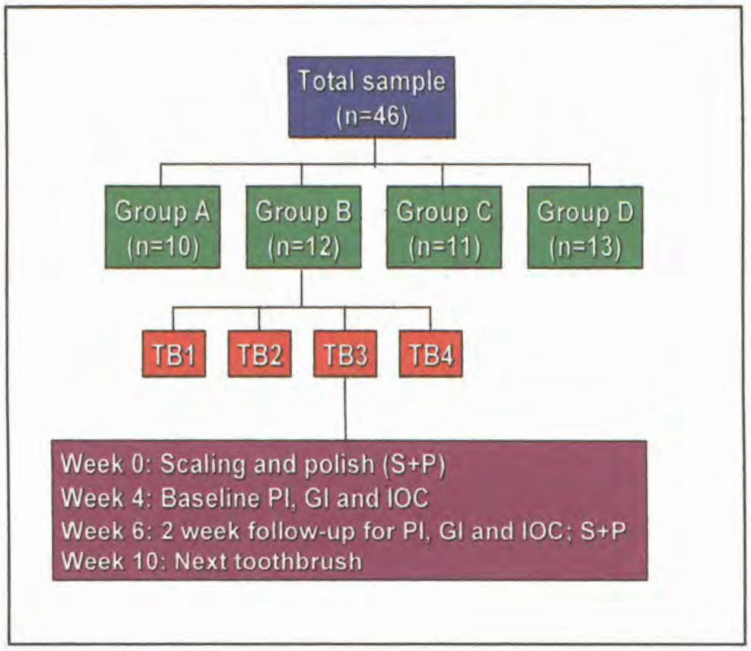

Figure 4: Experimental design

3.8 Data recording and analysis

3.8.1 Data form

The data form (Addendum A) was divided into two main sections:

i. Basic and personal information of the subject, i.e. name, age, sex, etc.

ii. The IOC, GI and PI at various time intervals as determined by the study design.

3.8.2 Data recording

At follow-up visits only the unique identifier was recorded for each patient which was assigned to each patient at the beginning of the trial. The name, age and sex of each patient was recorded only during the first visit. At the beginning and end of each brushing cycle the PI, GI and IOC were recorded.

3.8.3 Data Analysis

- **Comparison of Means**

The effectiveness of the four toothbrushes was compared by studying the mean PI, GI and IOC. For the PI, the Mean PI before (MPI (before)), Mean PI (MPI (after)) after and the Difference in MPI (DMPI) were compared. The GI was compared using Mean GI before (MGI (before)), Mean GI after (MGI (after)) and the Difference in MGI (DMGI). These comparisons were done by means of the commonly used Analysis of Variance (ANOVA) significance tests.

The Brown and Forsyth's statistical test was done to determine the homogenicity in variance of the data. This is a prerequisite for testing of means.

- **Correlation Analysis**

  It was deemed necessary to evaluate the level of agreement in IOC measurements with measurements in PI and GI. A high level of agreement would mean that a simpler and fast IOC measurement could be used instead of the well established PI and GI. For this purpose the Pearsons Correlation Coefficient was used.

3.9 Scheduling

The clinical trial was planned to run for 24 weeks starting in April 1998. Arrangements were made with the personnel of the Oral Hygiene Division to arrange the patient examinations and subsequent prophylaxis.

3.10 Summary

This Chapter described the cross-over longitudinal study design as well as all aspects involved in the implementation of the study. Chapter 4 gives a detailed description of the results together with the statistical analyses.

CHAPTER 4: RESULTS

4.1 Introduction

In order to make any conclusion, results have to be statistically evaluated. This chapter deals with comparing and evaluation of the results for PI, GI and IOC as well as toothbrush preference.

4.2 Analysis of Sample

Initially fifty patients were selected of which 4 withdrew due to a lack of compliance. Data was analysed for the remaining 46 patients. Ages ranged between 11 and 27 years with a mean age of 16 years, 7 months.

The patients were divided randomly into 4 groups, namely groups A, B, C and D (Table 2). Each group began with one of the 4 toothbrushes that were tested. The cross-over design enabled all the subjects to use all 4 of the toothbrushes by the end of the clinical trial.

Table 2: Age distribution of the study group

AGE	GROUP A n	GROUP B n	GROUP C n	GROUP D n	TOTAL n
11-13	1	3	3	1	8
14	2	1	1	1	5
15	3	3	3	4	13
16	2	-	1	2	5
17	1	1	-	2	4
18	1	1	1	1	4
19-20		1	-	2	3
21-27		2	2		4
Total	**10**	**12**	**11**	**13**	**46**
%	**21,7**	**26,1**	**23,9**	**28,3**	**100**

67,4% of the sample were female, 32,6% male (Table 3). There were no specific criteria for having twice as many females.

Table 3: Sex distribution of patient

SEX	GROUP A n	GROUP B n	GROUP C n	GROUP D n	TOTAL n
Female	6	4	9	12	31 (67,4%)
Male	4	8	2	1	15 (32,6%)
Total	**10**	**12**	**11**	**13**	**46**

4.3 Plaque Index

4.3.1 Plaque Index per tooth

Details of the MPI (before) and MPI (after) as well as the DMPI for all patients and for each tooth after using all 4 toothbrushes is shown in Table 4. The MPI per tooth ranged from 0,37 to 0,8. The DMPI was calculated by subtracting MPI (before) from MPI (after), thus a negative value meaning an improvement. The DMPI ranged from -0,14 (indicating the greatest improvement) to 0,08 (indicating a greater MPI after the use of a particular toothbrush). The DMPI is relatively small. This may be ascribed to very low baseline levels.

Figures 5 to 10 illustrate the DMPI per tooth using the 4 toothbrushes.

Table 4: Mean Plaque Index per tooth

Tooth No.	PI	Orthodontic Oral B		Oral B Advantage 30		Colgate Precision		Aquafresh	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
16	Before	0,60	0,58	0,57	0,48	0,55	0,43	0,49	0,42
	After	0,61	0,54	0,46	0,41	0,47	0,42	0,43	0,42
	DMPI	0,01	0,57	-0,11	0,52	-0,08	0,42	-0,06	0,47
22	Before	0,60	0,60	0,60	0,49	0,62	0,63	0,61	0,63
	After	0,68	0,65	0,64	0,55	0,48	0,50	0,52	0,50
	DMPI	0,08	0,65	0,04	0,67	-0,14	0,49	-0.09	0,52
24	Before	0,71	0,54	0,78	0,64	0,68	0,57	0,72	0,52
	After	0,73	0,55	0,8	0,54	0,61	0,42	0,65	0,49
	DMPI	0,02	0,56	0,02	0,62	-0,07	0,52	-0,07	0,40
36	Before	0,55	0,53	0,42	0,45	0,45	0,47	0,48	0,53
	After	0,49	0,61	0,47	0,41	0,37	0,47	0,48	0,54
	DMPI	-0,06	0,52	0,05	0,49	-0,08	0,42	0,00	0,55
42	Before	0,73	0,62	0,67	0,61	0,61	0,65	0,49	0,54
	After	0,60	0,63	0,72	0,57	0,60	0,61	0,53	0,54
	DMPI	-0,13	0,87	0,05	0,56	-0,01	0,60	0,04	0,53
44	Before	0,67	0,53	0,71	0,58	0,72	0,64	0,67	0,55
	After	0,64	0,66	0,71	0,51	0,63	0,50	0,56	0,46
	DMPI	-0,03	0,72	0,00	0,58	-0,09	0,62	-0,11	0,53

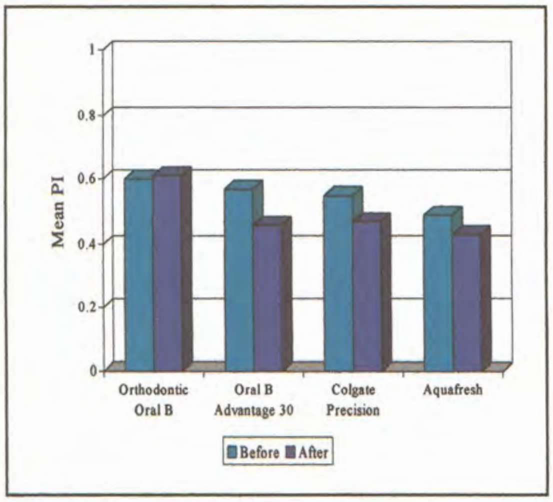

Figure 5: MPI of tooth 16

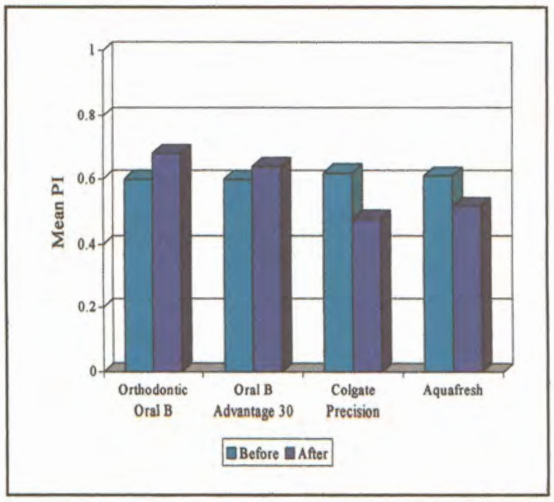

Figure 6: MPI of tooth 22

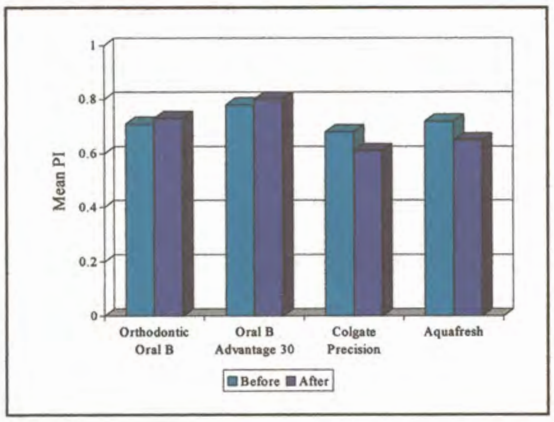

Figure 7: MPI of tooth 24

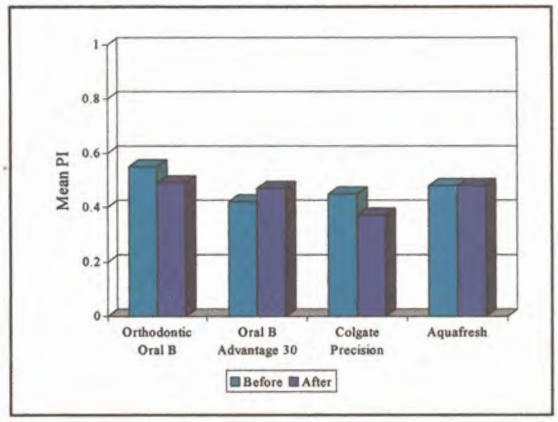

Figure 8: MPI of tooth 36

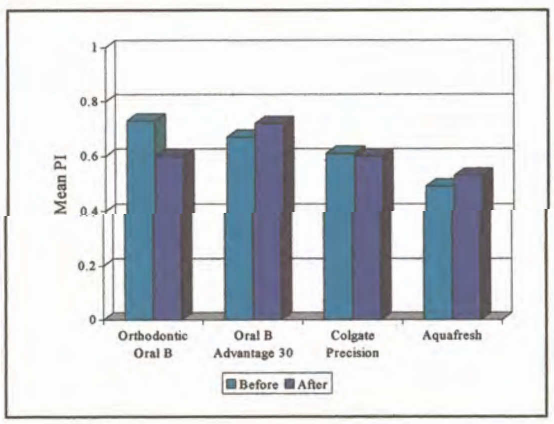

Figure 9: MPI of tooth 42

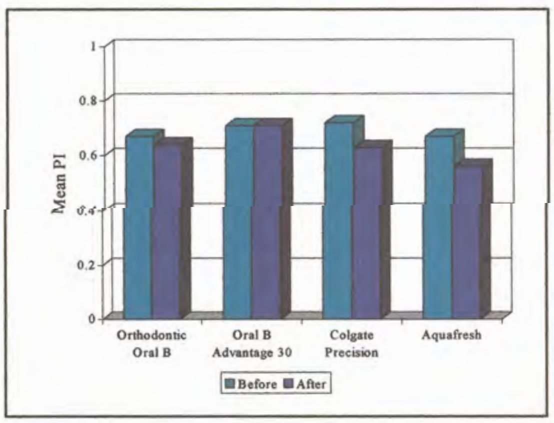

Figure 10: MPI of tooth 44

4.3.2 Plaque Index per mouth

The MPI before and after the use of each of the 4 toothbrushes is shown in Table 5. The MPI for all toothbrushes tested is below 1, indicating a low level of gingivitis. The DMPI ranges from –0,08 for the Colgate Precision to 0,00 for the Oral B Advantage 30 indicating little or no difference between the brushes when evaluating plaque removal.

Table 5: Mean Plaque Index per mouth

PI	TOOTHBRUSHES							
	Orthodontic Oral B		**Oral B Advantage 30**		**Colgate Precision**		**Aquafresh**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Before	0,64	0,38	0,63	0,39	0,61	0,42	0,58	0,38
After	0,63	0,46	0,63	0,33	0,53	0,36	0,53	0,33
DMPI	-0,01	0,35	0,00	0,35	-0,08	0,29	-0,05	0,22

Figure 11 illustrates the MPI for the various toothbrushes. There is little or no difference in the DMPI when using any of the toothbrushes. However, the MPI is relatively low, which may indicate a population with a relatively high dental IQ at the onset of the study.

4.3.3 Statistical Analysis

- **PI Scores**

  The ANOVA statistical procedure was used on a 5% level of significance to test MPI (before), MPI (after) and DMPI for any differences between the 4 toothbrushes.

  The p values of MPI (before), MPI (after) and DMPI for each tooth as well as for the PI per mouth are shown in Table 6.

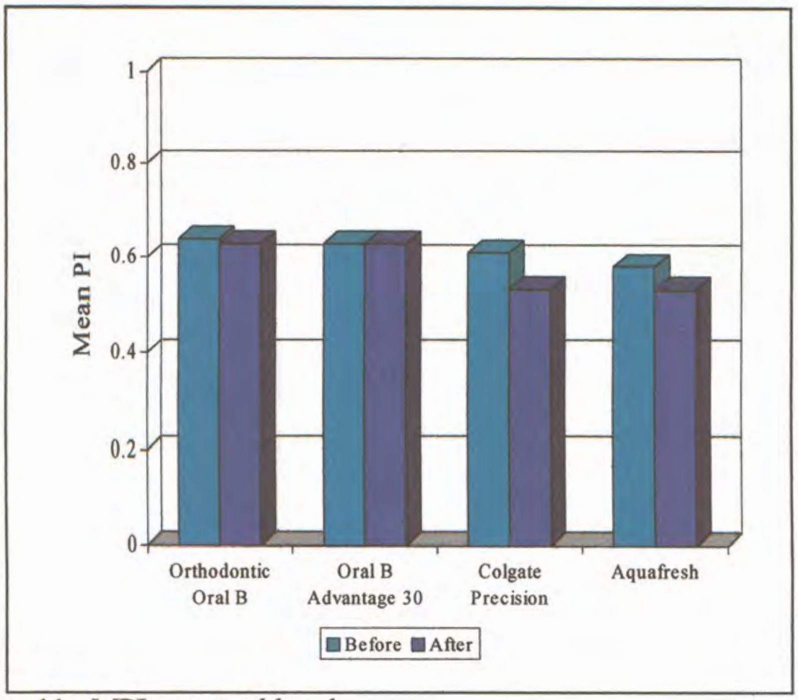

Figure 11: MPI per toothbrush

Table 6: p values for Plaque Index

TOOTH NUMBER	MPI (Before)	MPI (After)	DMPI
16	0,7435	0,2284	0,6485
22	0,9977	0,2547	0,2273
24	0,8723	0,2844	0,7464
36	0,6347	0,6495	0,5762
42	0,2738	0,5098	0,5542
44	0,9665	0,6336	0,8164
PI per mouth	**0,8722**	**0,3682**	**0,6050**

For all means tested p>0,05 it can therefore be concluded that the toothbrushes do not differ significantly in their ability to remove plaque in this study group.

The Brown and Forsyth's test for equality of variance for the MPI (before), MPI (after) and DMPI (for each tooth and the PI per mouth) resulted in p>0,05 for all tests. This indicated that the means were not significantly different and thus testing of means was justified.

4.4 Gingival Index

4.4.1 Gingival Index per tooth

As for the PI, each tooth was assessed for the GI as well. The results are shown in Table 7. The MGI ranges from 0,18 at baseline for tooth 22 when using the Aquafresh toothbrush to 0,67 after using the Oral B Advantage for tooth 16. These low values are indicative of a relatively low gingival inflammation. The DMGI ranges from –0,20 (indicating the best improvement) for tooth 24 using the Colgate Precision toothbrush to 0,19 (indicating a worsening) for tooth 16 using the Aquafresh toothbrush.

From the results it is evident that some teeth recorded a "worsening" of the GI after using a particular toothbrush. This is indicated by a positive value in the DMGI. A possible explanation for this is that the baseline values are very low and thus a slight difference will be easily detected.

4.4.2 Gingival Index per mouth

The MGI using the 4 toothbrushes is shown in Table 8. As for the PI, little or no difference was found in the DMGI for any of the 4 toothbrushes. The range of DMGI is from –0,13 for the Oral B Advantage showing the best improvement to 0,05 for the Aquafresh showing a worsening in the GI. These values indicate that they are not clinically significant as the difference is very small.

Figures 12 to 17 illustrate the effect of the various toothbrushes on the MGI per tooth.

Table 7: Mean Gingival Index per tooth

Tooth No.	GI	Orthodontic Oral B		Oral B Advantage 30		Colgate Precision		Aquafresh	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
16	Before	0,45	0,60	0,5	0,67	0,58	0,73	0,33	0,52
	After	0,58	0,76	0,67	0,73	0,48	0,64	0,52	0,65
	DMPI	0,13	0,69	0,17	0,95	-0,10	0,65	0,19	0,65
22	Before	0,35	0,54	0,33	0,53	0,27	0,49	0,18	0,40
	After	0,35	0,58	0,37	0,51	0,18	0,29	0,27	0,44
	DMGI	0,00	0,54	0,04	0,63	-0,09	0,44	0,09	0,44
24	Before	0,37	0,55	0,39	0,63	0,47	0,56	0,36	0,50
	After	0,29	0,57	0,40	0,55	0,27	0,50	0,39	0,49
	DMGI	-0,08	0,54	0,01	0,56	-0,20	0,57	0,03	0,52
36	Before	0,45	0,54	0,45	0,60	0,45	0,55	0,45	0,60
	After	0,39	0,64	0,35	0,47	0,30	0,48	0,35	0,43
	DMGI	-0,06	0,63	-0,10	0,51	-0,15	0,65	-0,10	0,61
42	Before	0,40	0,59	0,60	0,70	0,48	0,61	0,34	0,53
	After	0,43	0,65	0,46	0,58	0,32	0,57	0,38	0,45
	DMGI	0,03	0,63	-0,14	0,76	-0,16	0,53	0,04	0,68
44	Before	0,35	0,57	0,40	0,53	0,29	0,60	0,33	0,56
	After	0,36	0,66	0,35	0,42	0,29	0,54	0,36	0,42
	DMGI	0,01	0,57	-0,05	0,62	0,00	0,57	0,03	0,16

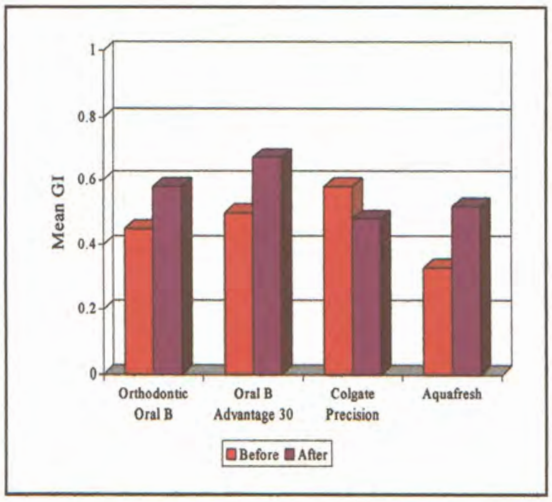

Figure 12: MGI of tooth 16

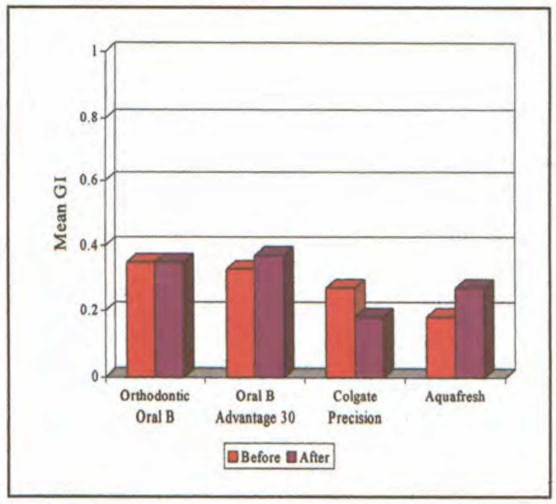

Figure 13: MGI of tooth 22

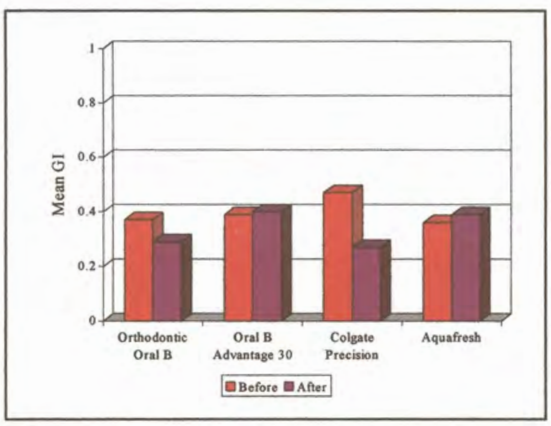

Figure 14: MGI of tooth 24

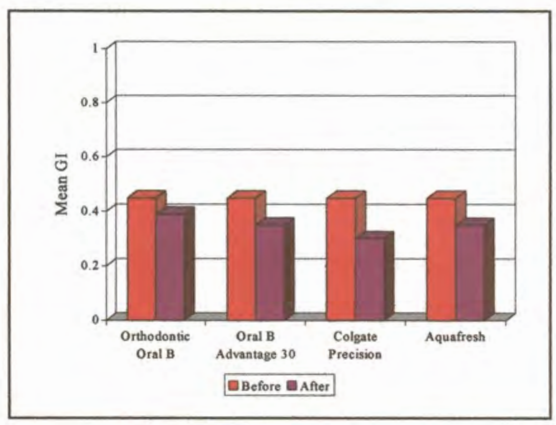

Figure 15: MGI of tooth 36

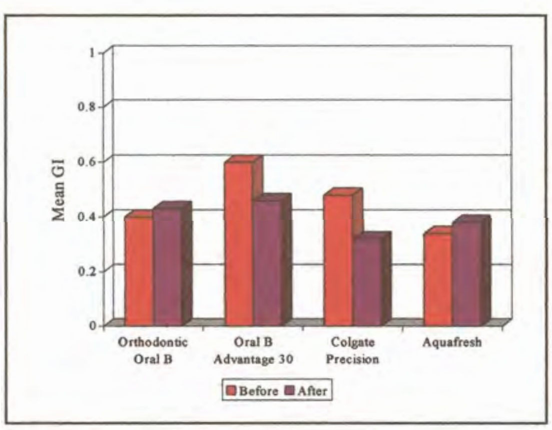

Figure 16: MGI of tooth 42

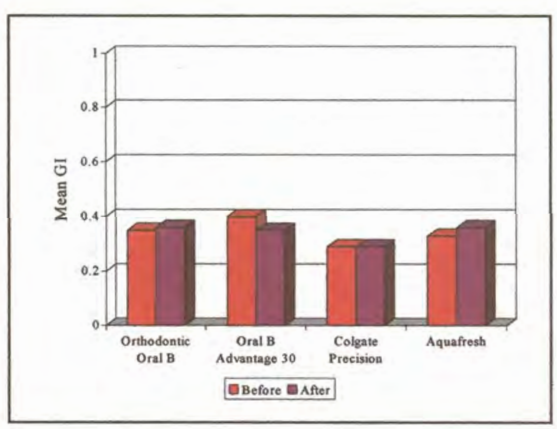

Figure 17: MGI of tooth 44

Table 8: Mean Gingival Index per mouth

	TOOTHBRUSHES							
GI	**Orthodontic Oral B**		**Oral B Advantage 30**		**Colgate Precision**		**Aquafresh**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Before	0,39	0,45	0,44	0,47	0,42	0,45	0,33	0,40
After	0,40	0,52	0,31	0,38	0,31	0,38	0,38	0,29
DMGI	0,01	0,38	-0,13	0,44	-0,11	0,39	0,05	0,36

Figure 18 illustrates the MGI for the various toothbrushes. Baseline levels for the GI are very low and thus any small change from these levels will not be clinically significant. The means are well below 1 and considering that only codes 0 and 2 were recorded, this again indicates a very low level of bleeding. Thus, the population studied shows a high levels of oral hygiene and dental IQ.

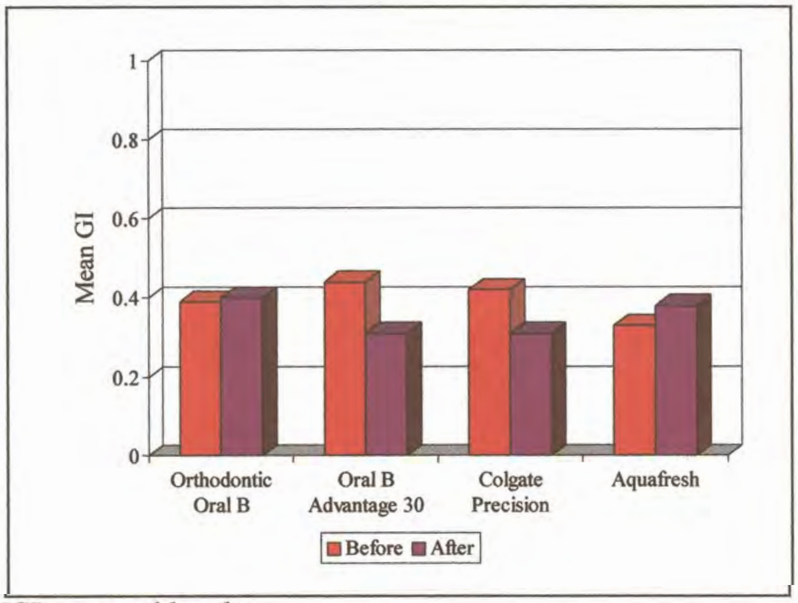

Figure 18: MGI per toothbrush

4.4.3 Statistical Analysis

- **GI per tooth**

  ANOVA was again used on a 5% level of significance to test MGI for all teeth as well as MGI per mouth before and after brushing with the 4 toothbrushes.

The p values of each tooth and using the 4 different toothbrushes for MGI (before), MGI (after) and DMGI are shown in Table 9.

Table 9: p values for Gingival Index

TOOTH NUMBER	MGI (Before)	MGI (After)	DMGI
16	0,2895	0,5719	0,2133
22	0,3929	0,2212	0,4192
24	0,7908	0,5399	0,1813
36	1,0000	0,8812	0,9237
42	0,2036	0,6400	0,2789
44	0,8255	0,9198	0,9091
GI per mouth	**0.6366**	**0.5051**	**0.2406**

As for the PI the p values are all >0,05. It can therefore be concluded that the toothbrushes are not significantly different from each other for all the teeth tested as well as the GI per mouth in reducing gingivitis.

However, specific comparisons indicated that there may be a difference in the DMGI between the Colgate Precision and Aquafresh toothbrushes. Colgate Precision has a DMGI of –0,11 compared to 0,04 for the Aquafresh toothbrush This indicates that for the GI the Colgate Precision may be slightly better than the Aquafresh. It should be noted that the GI was only improved slightly in the case of the Colgate Precision and this is not clinically significant.

4.5 Index of Oral Cleanliness

4.5.1 IOC (Before) vs IOC (After)

The IOC was done to determine the validity of the index in a population undergoing fixed orthodontic treatment. The Mean IOC before and after (MIOC (before), MIOC (after)) brushing with the 4 toothbrushes is shown in Table 10 and Figure 19. The MIOC (before) and MIOC (after) values are relatively low (below 1,85), indicating fairly good oral hygiene. There is little difference in MIOC (DMIOC) when using either of the 4 toothbrushes. The range is between –0,09 when using the Aquafresh toothbrush to 0,07 when using the Orthodontic Oral-B.

Table 10: Mean IOC before and after brushing

	TOOTHBRUSHES							
IOC	Orthodontic Oral B		Oral B Advantage 30		Colgate Precision		Aquafresh	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Before	1,76	1,22	1,85	1,33	1,70	1,35	1,61	1,31
After	1,83	1,37	1,80	1,31	1,30	1,21	1,52	1,15
DMIOC	0,07	1,37	-0,05	1,60	-0,40	1,39	-0,09	0,91

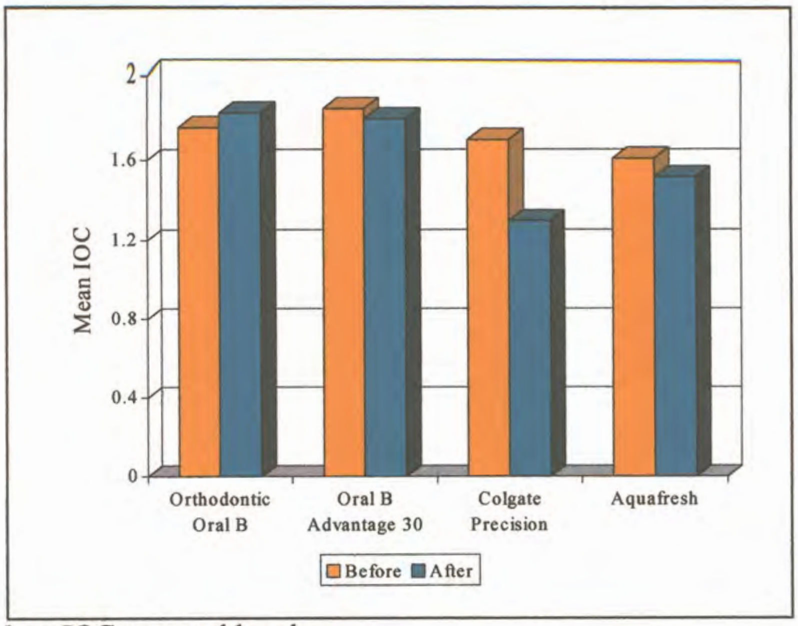

Figure 19: Mean IOC per toothbrush

4.5.2 Statistical Analysis

The IOC was correlated to the PI and GI by means of the Pearsons Correlation Coefficient and Coefficient of Determination.

Table 11 shows the correlation coefficients (r) (including their p values) and the coefficient of determination ($100r^2$) for PI vs IOC. The correlation has been calculated per toothbrush.

Table 11: Correlation coefficient and coefficient of determination for PI vs IOC

	TOOTHBRUSHES							
	Orthodontic Oral B		Oral B Advantage 30		Colgate Precision		Aquafresh	
	Before	After	Before	After	Before	After	Before	After
Correlation Coefficient (r)	0,73527	0,68857	0,62443	0,73129	0,75466	0,73416	0,83581	0,73773
P value	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001
Coefficient of Determination ($100r^2$) %	54,1	47,4	39,0	53,5	57,0	53,9	69,9	54,4

The range of the correlation coefficient is between 0,62443 to 0,83581. These are all highly significantly different from 0 (all p values <0,01). The coefficient of determination ranged from 39,0% to 69,9%. These values indicate that for the IOC compared to PI there was a highly significant correlation (p<0,01) but not a perfect correlation. (A perfect correlation would need a coefficient of determination of 100%).

Ideally a perfect correlation would be required to use the IOC as a substitute for the PI. The high level of correlation however, indicates that the IOC can be used as a screening procedure in orthodontic patients.

Table 12 shows the correlation between GI and IOC. As with the PI, the Pearsons Correlation Coefficient and Coefficient of Determination were calculated.

Table 12: Correlation coefficient and coefficient of determination for GI vs IOC

	Orthodontic Oral B		Oral B Advantage 30		Colgate Precision		Aquafresh	
	Before	After	Before	After	Before	After	Before	After
Correlation Coefficient (r)	0,40669	0,23678	0,38615	0,32490	0,42565	0,42008	0,44513	0,27486
P value	0,0050	0,1131	0,0080	0,0276	0,0032	0,0037	0,0019	0,0645
Coefficient of Determination ($100r^2$) %	16,5	5,6	14,9	10,5	18,1	17,6	19,8	7,6

The range of the correlation coefficient is between 0,23678 and 0,44513. These values are not significantly different from 0 (all p values <0,01). P values ranged from 0,0019 to 0,1131. The coefficient of determination ranged from 5,6% to 19,8%. The correlation between IOC and GI for any toothbrush is below 20%. These values indicate that for IOC compared to GI there was little or no correlation (p values between 0,0019 to 0,1131). It can thus be concluded that IOC cannot be used as a substitute for the GI.

From the analyses presented it can be assumed that the IOC can be used as an indicator of plaque in patients undergoing fixed orthodontic therapy. The GI is a determination of gingival bleeding and this is not correlated by the IOC.

4.6 Toothbrush Preference

At the end of the trial period each patient was questioned about his/her personal preference for one of the toothbrushes used in the study. The Colgate Precision was the most popular amongst patients with 45,7% of patients preferring this toothbrush. The least popular was the specifically designed Orthodontic Oral B toothbrush with only 4,3% choosing this brush. 23,9% preferred the Oral B Advantage 30 toothbrush while the Aquafresh toothbrush was preferred by 26,1%. Figure 20 illustrates these findings.

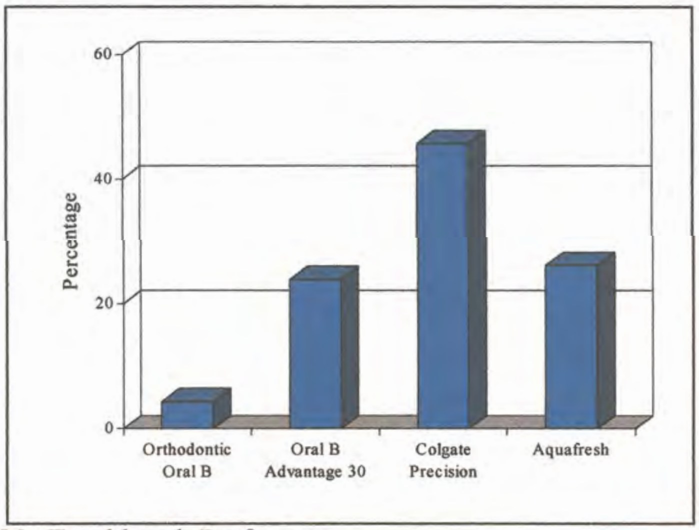

Figure 20: Toothbrush Preference

4.6.1 Statistical Analysis

In order to evaluate the degree of agreement between a patients preferred toothbrush and their "best" toothbrush (as measured by the DMPI and DMGI) the percentage where preference agreed with effectiveness was calculated. In only 9 patients (19,6%) did the DMPI (largest negative value) agree to their toothbrush preference.

The same results was found for agreement between the DMGI (largest negative value) and toothbrush preference (9 patients (19,6%)). There is thus no correlation between toothbrush preference and effective oral hygiene in patients undergoing orthodontic treatment.

When comparing the individual toothbrushes to DMPI, the Colgate Precision toothbrush accounted for 44,5%, Aquafresh toothbrush for 33,3% while the Oral B Advantage 30 accounted for 22,2% of the correlation. There was no correlation between the Orthodontic Oral B and patient preference.

For the DMGI, the Colgate Precision toothbrush accounted for 66,7% of the correlation, while the Oral B Advantage 30 and Aquafresh toothbrushes accounted for 22,2% and 11,1% respectively. Again there was no correlation between patient preference and the specifically designed Orthodontic Oral B toothbrush. These results can be accounted for by the patients preference for the Colgate Precision toothbrush.

4.7 Summary

From the results and statistical analyses it can be seen that there is a low level of plaque and gingivitis in the population studied before and after each toothbrush used. Little difference was found between the after vs before recordings for both the PI, GI and IOC. This may account for the statistical findings, i.e. there is no statistical difference in the effectiveness of the four different manual toothbrushes in patients with fixed orthodontic appliances.

The IOC may be used as a screening for plaque, however, there was no correlation to GI (bleeding).

There is no correlation between toothbrush preference and effective oral hygiene.

Chapter 5 will deal with a discussion of the results, conclusions drawn from the study and recommendations as a result of this study.

CHAPTER 5: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Introduction

The study was designed to evaluate:

i. the effectiveness of 4 different toothbrushes in patients undergoing fixed orthodontic therapy

ii. correlation between the Index of Oral Cleanliness (IOC) and either the Plaque Index (PI) or Gingival Index (GI)

iii. correlation between patient toothbrush preference and effective oral hygiene.

Each of the manufacturers claim superiority of their particular toothbrush design. The Oral-B Orthodontic has a longitudinal groove in the brushing surface to facilitate brushing around brackets and arch wires. The Aquafresh toothbrush has a unique flexible head. Soparkar *et al* (1991) claim that the Aquafresh design is more acceptable to patients and the flexible head allows for better cleaning and thus improved oral hygiene. The Colgate Precision toothbrush was designed to make up for a less than adequate toothbrushing technique (Mintel and Crawford, 1992). It is believed that this distinction in design accounts for Colgate Precision's clinical superiority (Sharma *et al*, 1992). The Oral B 30 is a toothbrush that has been widely used and tested. Grossman *et al* (1994) showed increased plaque removal with the Oral B 30. The softness of this toothbrush has also been well documented (Rawls *et al*, 1993). It is concluded that the potential for harming dental tissue is less for the Oral B than any of the other toothbrushes tested.

The cross-over design enabled each brush to be tested on each patient. This eliminated any potential for inter subject variation which may result from different number of brackets or types of components in the appliance.

Patient instructions were standardised. It was recommended that each subject uses the toothbrush for 2 minutes, twice per day.

5.1.2 Summary of results

The main findings of this study were:

i. a relatively low PI, GI and IOC at baseline and after brushing with each toothbrush.
ii. A two week brushing programme with any of the toothbrushes did not significantly affect the PI, GI and IOC.
iii. There was a significant but not absolute correlation between the IOC and PI.
iv. There was no correlation between the IOC and GI.
v. There was no correlation between toothbrush preference and effective oral hygiene for the patients.

The results of this study showed that the PI and GI were already low at baseline. This is different to that shown by Heasman *et al* (1998) and Heintze *et al* (1996) where plaque scores at all surfaces were greater than 50% at baseline. Several reasons may account for this difference. Firstly, the patients treated at the University of Pretoria orthodontic programme undergo vigorous selection procedures before being selected. Secondly, the dental IQ of these patients is generally higher. Orthodontic therapy at the University of Pretoria is a privilege offered to these patients. Thirdly, these patients are constantly monitored, and any deterioration in oral hygiene is immediately rectified.

There was no statistical difference in the Difference in Mean Plaque Index (DMPI) when comparing the 4 toothbrushes tested. However, when comparing the Difference in Mean Gingival Index (DMGI), the Colgate Precision seems to be more effective than the Aquafresh toothbrush. The p value obtained was 0,0495 which is <0,05 and thus these brushes were significantly different at the 95% level. There was no statistical difference amongst the other toothbrushes.

According to the results of this study the IOC is correlated to the PI. There is no correlation between the IOC and GI. The IOC does give a good and quick evaluation of the oral hygiene status of patients as suggested by Bearn *et al* (1996).

On the relation of patient preference of a toothbrush to effective oral hygiene one would expect little or no correlation. Patient preference is often influenced by factors such as marketing, previous experience and in today's economic climate, cost. No correlation of patient preference and effective oral hygiene has been reported in the literature. It is be suggested that such a correlation study could be added to future toothbrush studies.

5.2 Conclusion

The following conclusions can be drawn from this study:

i. This study has confirmed the premise that there is no difference in the effectiveness of the four toothbrushes tested in plaque control of patients undergoing fixed orthodontic appliances.
ii. The IOC can be used as a screening of oral hygiene status in patients undergoing orthodontic therapy (measure of plaque on the tooth surface). The IOC cannot be used as a measure of gingivitis (bleeding index).
iii. Patient preference is usually dependant on effective marketing and not on the effectiveness of the brush.

5.3 Recommendations

i. Oral hygiene criteria should be used in the selection of orthodontic patients. Patients with a low PI and GI score showed little difference in oral hygiene scores after the use of either of the 4 toothbrushes.

ii. The IOC should be further investigated before it is used in evaluating effectiveness of oral hygiene procedures in orthodontic patients.

iii. The IOC can be used as a screening procedure in patients undergoing fixed orthodontic therapy.

IT IS NOT THE BRUSH WHICH DETERMINES EFFECTIVE PLAQUE REMOVAL, BUT HOW YOU BRUSH!

REFERENCES

Agerbeck N, Melsen B and Rolla G (1975) Application of chlorhexidine by oral irrigation systems, *Scandinavian Journal of Dental Research*, **83** : 284-287.

Ainamo J and Ainamo A (1978) Development of oral health during dental studies in India and Finland. *International Dental Journal*, **28** : 427.

Ainamo J, Barmes D, Beagrie G, Cutress T, Martin J and Sardo-Infirri J (1982) Development of the World Health Organisation (WHO) Community Periodontal Index of Treatment Needs (CPITN) *International Dental Journal*, **32** : 281-291.

Alexander AG (1971) A study of the distribution of supra and subgingival calculus, bacterial plaque and gingival inflammation in the mouths of 400 individuals. *Journal of Periodontology*, **42** : 21-28.

Alexander SA (1991) Effects of orthodontic attachments on the gingival health of permanent second molars. *American Journal of Orthodontics and Dentofacial Orthopedics*, **100** :337-340.

Alstad S and Zachrisson BW (1979) Longitudinal study of periodontal condition associated with orthodontic treatment in adolescents, *American Journal of Orthodontics*, **76** : 277-286.

Årtun J and Brobakken BO (1986) Prevalences of carious white spots after orthodontic treatment with multibanded appliances. *European Journal of Orthodontics*, **8** : 229-234.

Aziz-Gandour IA and Newman NH (1986) The effects of a simplified oral hygiene regime plus supragingival irrigation with chlorhexidine or metronidazole on chronic inflammatory periodontal disease. *Journal of Clinical Periodontology*, **13** : 228-236.

Battista GW and Petrone DM (1993) Comparison of the laboratory interproximal access efficacy of the Colgate Precision toothbrush and the Crest Complete toothbrush. *Journal of Clinical Dentistry,* **4** : D5-D7.

Bearn DR, Aird JC, Jenkins WMM and Kinane DF (1996) Index of Oral Cleanliness (IOC). A new oral hygiene index for use in clinical audit. *British Journal of Orthodontics*, **23** : 145-151.

Berglund LR and Small CL (1990) Effective oral hygiene for orthodontic patients. *Journal of Clinical Orthodontics*, **25** : 315-320.

Boyd RL (1983) Longitudinal evaluation of a system for self-monitoring plaque control effectiveness in orthodontic patients. *Journal of Clinical Periodontology*, **10** : 380-388.

Boyd RL and Rose CM (1994) Effect of rotary electric toothbrush versus manual toothbrush on decalcification during orthodontic treatment. *American Journal of Orthodontics and Dentofacial Orthopedics*, **105** : 450-456.

Brightman LJ, Terezhalmy GT, Greenwell H, Jacobs M and Enlow DH (1991) The effects of a 0.12% chlorhexidine gluconate mouthrinse on orthodontic patients aged 11 through 17 with established gingivitis. *American Journal of Orthodontics and Dentofacial Orthopaedics*. **100** : 324-329.

Buckley LA (1980) The relationships between irregular teeth, plaque, calculus and gingival disease, *British Dental Journal*, **148** : 67-69.

Burch JG, Lanese R and Ngan P (1994) A two-month study of the effects of oral irrigation and automatic toothbrush use in an adult orthodontic population with fixed appliances. *American Journal of Orthodontics and Dentofacial Orthopaedics*, **106** : 121-126.

Burkett LW (1963) Effects of orthodontic treatment on the soft periodontal tissues (1963) *American Journal of Orthodontics*, **49** : 660-671.

Chatterjee R and Kleinberg I (1979) Effect of orthodontic band placement on the chemical composition of human incisor tooth plaque. *Archives of Oral Biology*, **24** : 97-100.

Cianco SG (1988) Use of mouthrinses for professional indications. *Journal of Clinical Periodontology*, **15** : 520-523.

Cohen AM, Moss JP and Williams DW (1983) Oral hygiene instruction prior to orthodontic treatment. A preliminary study. *British Dental Journal*, **16** : 277-278.

Croxson LJ (1984) A simplified periodontal screening examination: The community periodontal index of treatment needs (WHO) in general practice. *International Dental Journal*, **34** : 28-34.

Cumming BR and Loe H (1973) Consistency of plaque distribution in individuals without special home care instruction. *Journal of Periodontal Research*, **8** : 94-100.

Cutress TW, Ainamo J and Sardo-Infirri I (1987) The community periodontal index of treatment needs (CPITN) procedure for population groups and individuals. *International Dental Journal*, **9** : 192-196.

Davies TM, Shaw WC, Worthington HV, Addy M, Dummer P and Kingdon A (1991) The effect of orthodontic treatment on plaque and gingivitis, *American Journal of Orthodontics and Dentofacial Orthopaedics*, **99** : 155-162.

Deasy MJ, Singh SM, Kemp JH, Curtis JP, Rustogi KN and Fung K (1993) A clinical comparison of plaque removal performance of three manual toothbrushes. *Journal of Clinical Dentistry*, **4** (Supplement D) : D17-21.

Diedrich P (1981) Enamel alteration from bracket bonding and debonding. A study with the electron microscope. *American Journal of Orthodontics*, **79** : 500-522.

Dorfman HS (1978) Mucogingival changes resulting from mandibular incisor tooth movement, *American Journal of Orthodontics*, **74** : 286-297.

Emslie RD (1980) The 621 periodontal probe. *International Dental Journal*, **39** : 287.

Fraudsen A (1986) Mechanical oral hygiene practices. State-of-the-science review. In: *Dental Plaque Control Measures and Oral Hygiene Practices Proceedings from a State-of-the-Science Workshop,* Loe H Kleinman DV, Eds., IRL Press Ltd., Oxford , 93-116.

Geiger AM, Gorelick L, Gwinnett AJ and Griswold PG (1988) The effect of a fluoride program on white spot formation during orthodontic treatment, *American Journal of Orthodontics*, **93** : 29-37.

Gjermo P and Flotra L (1970) The effect of different methods of interdental cleaning. *Journal of Periodontal Research*, **5** : 230-236.

Gorelick L, Geiger AM and Gwinnett AJ (1982) Incidence of white spot formation after bonding and banding. *American Journal of Orthodontics*, **81** : 83-98.

Gortjamanos T, Singh H and Strangio T (1992) Choice of toothbrush: a survey of dentists' personal preferences and recommendations for patients. *Australian Dental Journal* **37** : 290-295.

Greene JC and Vermillion JR (1960) The oral hygiene index: A method for classifying oral hygiene status. *Journal of the American Dental Association,* **61** : 172.

Grossman E, Dembling W and Walley DR (1994) Two long-term clinical studies comparing the plaque removal and gingivitis reduction efficacy of the Oral-B Advantage Plaque Remover to five manual toothbrushes. *Journal of Clinical Dentistry* **5** : 46-53.

Heasman P, Wilson Z, Macgregor I and Kelly P (1998) Comparative study of electric and manual toothbrushes in patients with fixed orthodontic appliances. *American Journal of Orthodontics and Dentofacial Orthopedics,* **114** : 45-49.

Heintze SD, Jost-Brinkman PG and Loundos J (1996) Effectiveness of three different types of electric toothbrushes compared with a manual technique in orthodontic patients. *American Journal of Orthodontics and Dentofacial Orthopaedics*, **110** : 630-638.

Hirschfeld I (1939) *The Toothbrush: Its Use and Abuse.* Dental Items of Interest Publishing Co., Inc. Brooklyn, 43-70.

Huser MC, Baehni PC and Lang R (1990) Effects of orthodontic bands on microbiological and clinical parameters. *American Journal of Orthodontics and Dentofacial Orthopaedics*, **97** : 213-218.

Jackson CL (1991) Comparison between electric toothbrushing and manual toothbrushing, with and without oral irrigation, for oral hygiene of orthodontic patients. *American Journal of Orthodontics and Dentofacial Orthopedics* **99** : 15-20.

Johansen JR, Gjermo P and Bellini HT (1973) A system to classify the need of periodontal treatment. *Acta Odontology Scandinavia*, **31** : 297-305.

Kessler M (1976) Interrelationships between orthodontics and periodontics. *American Journal of Orthodontics*, **70** : 154-177.

Kiliçoglu M, Yildirim M and Polater H (1997) Comparison of the effectiveness of two types of toothbrushes on the oral hygiene of patients undergoing orthodontic treatment with fixed appliances. *Journal of Orthodontics and Dentofacial Orthopaedics* , **111** : 591-594.

Klein H and Palmer CE (1938) Dental caries in American Indian children *Public Health Bulletin* (Washington), No 239.

Kloehn JS and Pfeifer JS (1974) The effect of orthodontic treatment on the periodontium, *Angle Orthodontist*, **44** : 127-134.

Lang NP, Cumming BR and Löe H (1973) Toothbrushing frequency as it related to plaque development and gingival health. *Journal of Periodontology*, **44** : 396-405.

Legott PJ, Boyd RL, Quinin RS, Eakle WS and Chambers DW (1984) Gingival disease pattern during fixed orthodontic treatment adolescents vs adults. *Journal of Dental Research*, **63** : 309 (Abstract 1245).

Lilienthal B, Amerena V and Gregory G (1965) An epidemiological study of chronic periodontal disease. *Archives of Oral Biology*, **10** : 553-566.

Lindhe J, Hamp SE and Löe H (1975) Plaque induced periodontal disease in Beagle dogs. *Journal of Periodontology*, **10** : 243.

Löe H (1967) The Gingival Index, the Plaque Index and the Retention Index systems. *Journal of Periodontology*, **38** : 610.

Löe (1971) Human research model for the production and prevention of gingivitis. *Journal of Dental Research*, **50** : 256-264.

Löe H, Theilade E and Jensen SB (1965) Experimental gingivitis in man. *Journal of Periodontology*, **36** : 177-187.

Lövdal A, Arno A, Schei O and Waerhaug J (1961) Combined effect of subgingival scaling and controlled oral hygiene on the incidence of gingivitis. *Acta Odontology of Scandinavia*, **19** : 537.

McGlynn FD, LeCompte DJ, Thomas RG, Courts KJ and Melamed BG (1987) Effects of behavioural self-management on oral hygiene adherence among orthodontic patients. *American Journal of Orthodontics and Dentofacial Orthopaedics*, **91** : 15-21.

Mintel TE and Crawford J (1992) The search for a superior toothbrush design technology. *Journal of Clinical Dentistry*, **3** : C1-C4.

Mitchell L (1992) Decalcification during orthodontic treatment with fixed appliances – an overview. *British Journal of Orthodontics*, **19** : 199-205.

Mizrahi E (1983) Surface distribution of enamel opacities following orthodontic treatment. *American Journal of Orthodontics*, **84** : 323-331.

Ogaard B, Rolla G and Arends J (1988) Orthodontic appliances and enamel demineralisation. Part 1. Lesion development. *American Journal of Orthodontics and Dentofacial Orthopedics*, **94** : 68-73.

Ogaard B (1989) Prevalence of white spot lesions in 19-year-olds: a study on untreated and orthodontically treated persons 5 years after treatment. *American Journal of Orthodontics and Dentofacial Orthopedics*, **96** : 423-427.

O'Reilly MM and Featherstone JD (1987) Demineralisation and remineralization around orthodontic appliances: An in vivo study. *American Journal of Orthodontics and Dentofacial Orthopaedics*, **92** : 33-40.

Page RC and Schroeder HE (1981) Current status of the host response in chronic marginal periodontitis. *Journal of Periodontology*, **52** : 477.

Parfitt GJ (1957) A five year longitudinal study of the gingival condition of a group of children in England. *Journal of Periodontology*, **28** : 26.

Pritchard JF (1975) The effect of bicuspid extraction orthodontics on the periodontium, *Journal of Periodontology*, **46** : 534-542.

Ramfjord SP (1959) Indices for prevalence and incidence of periodontal disease. *Journal of Periodontology*, **30** : 51.

Rawls HR, Smith NK, Lentz DL, Cobb GW Jr and Bailey MS (1993) An electron microscopic comparison of bristle end-rounding of three commercial toothbrushes. *Journal of Clinical Dentistry* **4** : 96-100.

Reardon RC, Cronin M, Balbo F, Schiff T, Menaker L, Weatherford TW 3rd, Walley D, Vidra J, and Zib K (1993) Four clinical studies comparing the efficacy of flat-trim and multi-level trim commercial toothbrushes. *Journal of Clinical Dentistry*, **4** : 101-105.

Regezi JA and Sciubba JJ (1989) Oral Pathology: Clinical-Pathological Correlations. WB Saunders Company, Philadelphia, PA, USA, 488-499; 508-512.

Rosendahl PO (1962) Toothbrushing, yesterday, tomorrow. *Southern Californian Dental Association Journal*, **30** : 210-213.

Russell AL (1956) A system of classification and screening of prevalence surveys of periodontal disease. *Journal of Dental Research*, **35** : 350.

Russell AL (1963) International nutrition surveys: A summary of preliminary dental findings. *Journal of Dental Research*, **42** : 232.

Sadowsky and BeGole (1981) Longterm effects of orthodontic treatment on periodontal health, *American Journal of Orthodontics and Dentofacial Orthopaedics*, **80**: 156-172.

Saxen L (1980) Juvenile periodontitis. *Journal of Clinical Periodontology*, **7** : 1.

Schour I and Massler M (1947) Gingival disease in postwar Italy (1945). I Prevalence of gingivitis in various age groups. *Journal of the American Dental Association*, **35** : 475.

Shafer WG, Hine MK and Levy BM (1984) A textbook of Oral Pathology, 4th edition. WB Saunders Company, Tokyo, Japan, 406-468; 772-778.

Sharma NC, Galustians J, Rustogi KN, McCool JJ, Petrone M, Volpe AR, Korn LR and Petrone D (1992) Comparative plaque removal efficacy of three toothbrushes in two independent clinical studies. *Journal of Clinical Dentistry* **3** : C13-C20.

Sharma NC, Galustians J, McCool JJ, Rustogi KN and Volpe AR (1994) The clinical effects on plaque and gingivitis over three month's use of four complex design manual toothbrushes. *Journal of Clinical Dentistry*, **5** : 114-118.

Singh SM, Rustogi KN, McCool JJ, Petrone M, Volpe AR, Korn LR and Petrone D (1992) Clinical studies regarding the plaque removal efficacy of manual toothbrushes. *Journal of Clinical Dentistry*, **3** (Supplement C) : C21-28.

Soares JV and Southam JC (1993) Oral Pathology, 2nd edition. Oxford Medical Publications, Hong Kong, 19-33; 91-107.

Soparkar PM, Newman MB and De Paola PF (1991) The efficacy of a novel toothbrush design. *Journal of Clinical Dentistry*, **2** : 107-10.

Stuteville OH (1937). Injuries caused by orthodontic appliances and methods of preventing these injuries. *Journal of the American Dental Association*, **24** : 1494-1507.

Trimpeneers LM, Wijgaerts IA, Grognard NA, Dermaut LR and Adriaens PA (1997) Effect of electric toothbrushes versus manual toothbrushes on removal of plaque and periodontal status during orthodontic treatment. *American Journal of Orthodontics and Dentofacial Orthopaedics*, **111** : 492-497.

Trossello VK and Gianelly AA (1979) Orthodontic treatment and periodontal status, *Journal of Periodontology*, **50** : 665-671.

Volpenheim DW, Walsh ME, Dellerman PA and Burkett TA (1994) A new method for *in vitro* evaluations of the interproximal penetration of manual toothbrushes. *Journal of Clinical Dentistry*, **5** : 27-33.

Wilkins EM (1989) Clinical Practice of the Dental Hygienist, 6th edition. Lea and Febiger, Philadelphia, PA, USA, 235-246; 337-341; 366-358.

Wong CH and Wade AB (1985) A comparative study of effectiveness in plaque removal by Super Floss and waxed dental floss. *Journal of Clinical Periodontology*, **12** : 788-795.

Yankell SL, Edvardsen S, Braaten S and Emling RC (1993) Laboratory and clinical evaluations of the Jordan Exact toothbrush. *Journal of Clinical Dentistry,* **4** : 67-70.

Yankell SL, Shi X and Emling RC (1992) Comparative laboratory evaluation of three toothbrushes regarding interproximal access efficacy. *Journal of Clinical Dentistry* **3** : C5-C8.

Yankell SL, Shi X and Emling RC (1993) Comparative laboratory evaluation of two new toothbrushes regarding interproximal access efficacy. *Journal of Clinical Dentistry,* **4** : D1-D4.

Yankell SL, Shi X and Emling RC (1994) Laboratory interproximal access efficacy of two compact manual toothbrushes. *Journal of Clinical Dentistry,* **4** : 111-113.

Yost KG, Miluszewski KF and Chen AC (1994) Laboratory evaluations of toothbrush interproximal penetration ratios. *Journal of Clinical Dentistry,* **4** : 125-127.

Zachrisson BU and Alnaes L (1973) Periodontal condition in orthodontically treated and untreated children. Loss of attachment, gingival pocket depth and clinical crown heights, *Angle Orthodontist,* **43** : 402-411.

Zachrisson BU (1974) Oral hygiene for orthodontic patients: Current concepts and practical advice. *American Journal of Orthodontics,* **66** : 487-497.

Zachrisson BU (1975) Cause and prevention of injuries to teeth and supporting structures during orthodontic treatment. *American Journal of Orthodontics*, **69** : 285-300.

Zachrisson BU and Alnaes L (1974) Periodontal condition in orthodontically treated and untreated individuals, *Angle Orthodontist*, **44** : 48-55.

Zachrisson S and Zachrisson BU (1972) Gingival condition associated with orthodontic treatment, *Angle Orthodontist*, **42** : 26-34.

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ADDENDUM A

TOOTHBRUSH PROJECT – DR A LAHER – T97157 – ORT9005

1. Examiner number		V1:1					
2. Registration number			V2:2-3				
3. Gender		V3:4					
4. Date of Birth (YYMMDD)							V4:5-10
5. Name of Patient							
6. Date of Examination (YYMMDD)							V5:11-16
7. Group		V6:17					
8. Week Number		V7:18					
9. Toothbrush Type		V8:19					

10. Index of Oral Cleanliness (IOC)

	V9:20

11. Plaque Index (PI)

	16	22	24	36	42	44	
DB							V10-V15:21-26
B							V16-V21:27-32
MB							V22-V27:33-38
L							V28-V33:39-44

12. Gingival Index (GI)

	16	22	24	36	42	44	
DB							V34-V39:45-50
B							V40-V45:51-56
MB							V46-V51:57-62
L							V52-V57:63-68

13. Form number				V58:69-71