Soft tissue profile changes in patients treated with non-extraction versus second premolar extraction protocols - using the Damon system.

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KEYWORDS

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Second premolar extraction

Non - extraction

Cephalometric analysis

Damon System

Self-ligating brackets

Fixed appliance

Holdaway soft tissue analysis

ABSTRACT

SOFT TISSUE PROFILE CHANGES IN PATIENTS TREATED WITH NON-EXTRACTION VERSUS SECOND PREMOLAR EXTRACTION PROTOCOLS - USING THE DAMON SYSTEM.

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Introduction:

Orthodontic treatment has the ability to improve the aesthetics and the function of patients. In order to create space, orthodontic treatment often requires removal of teeth. The most common teeth removed for orthodontic treatment are the premolars. It has become popular to remove second premolars in certain cases where the soft tissue profile should not be altered.

The Damon self-ligating orthodontic system is renowned for not requiring dental extractions in the majority of cases. The effect of extractions on the soft tissue profile of patients, in conjunction with using the Damon system, has therefore not been researched. It is important to understand the effect that orthodontic treatment and extractions can have on the soft tissue profile of patients. This effect can accurately be determined by making use of the soft tissue cephalometric analysis, developed by Dr Reed A. Holdaway in 1983.

Aims and objectives:

The aim of this study was to compare the soft tissue profile changes of extraction (second premolars) and non-extraction cases before and after orthodontic treatment.

The objective of the study was to make use of lateral cephalometric radiographs and the Holdaway cephalometric analysis to quantify and compare the soft tissue profile of subjects treated with second premolar extractions, and without extractions, before treatment commenced. The same method was then used to measure the soft tissue profile of the subjects, after treatment was finished.

Another objective was to compare the extraction and non-extraction subjects' soft tissue profile changes. The amount and extent of soft tissue changes that can be expected when second premolars are removed compared to non-extraction was determined for orthodontic treatment using the Damon system.

Methodology:

The sample was retrospectively selected from the practice of one specialist orthodontist, who is certified by the Health Professions Council of South Africa. The Orthodontist has more than 25 years of experience and exclusively makes use of the Damon orthodontic system.

The sample was chosen after a propensity score matching was performed using maxillary and mandibular crowding, as well as the lower incisor inclination, as measured before treatment.

The initial (T1) and final (T2) lateral cephalometric radiographs of 60 cases were taken by the same cephalostat machine.

The cases were divided into two groups according to the presence or absence of second premolar extractions in their treatment plans.

Of the 60 cases, 25 had extractions of the second premolars in both the maxilla and mandible, and the other 35 received orthodontic treatment without any extractions.

The study was designed to be a retrospective study evaluating and comparing the soft tissue profile changes in non-extraction, and second premolar extraction cases. The Holdaway cephalometric analysis, a soft tissue analysis developed by Dr Reed A. Holdaway (1983), was used to conduct the study. The analysis is composed of eleven measurements, nine linear and two angular.

Results:

Evaluating the Holdaway measurements from start to completion of treatment showed the following:

The **extraction** group showed an increase in the following values:

- Superior sulcus depth (0.34 mm)
- Upper lip thickness at vermillion border (1.78 mm)
- Inferior sulcus to H-line (0.30 mm)
- Nasal prominence (1.38 mm)
- Facial angle (0.89°)

The **non-extraction** group showed an increase in the following values:

- Lower lip to H-line (0.91 mm)
- Superior sulcus depth (0.67 mm)
- Soft tissue subnasale to H-line (1.08 mm)
- Upper lip thickness at A-point (0.54 mm)
- Upper lip thickness at vermillion border (0.04 mm)
- Inferior sulcus to H-line (0.04 mm)
- Facial angle (0.89°)
- H-angle (0.64°)
- Chin thickness (0.25 mm)

The **extraction** group showed a decrease in the following values

- Skeletal profile convexity (-0.94 mm)
- Lower lip to H-line (-0.65 mm)
- Soft tissue subnasale to H-line (-0.87 mm)
- Upper lip thickness at A-point (-0.70 mm)
- Chin thickness (-0.23 mm)
- H-angle (-1.62°)

The **non-extraction** group showed a decrease in:

- Skeletal profile convexity (-1.0 mm)
- Nasal prominence (-0.18 mm)

The results of the intergroup analysis done by the two one-sided significance tests (TOST) showed equivalence for all 11 Holdaway analysis measurements in the intergroup analysis, indicating that both the extraction and non-extraction groups showed similar soft tissue profile changes at the end of treatment with the Damon system.

Conclusion:

Soft tissue profile changes of the extraction (upper and lower second premolar) and non-extraction groups, showed similar results. There was therefore not a significant difference in soft tissue response for the two treatment groups.

The Damon system can be used in conjunction with upper and lower second premolar extractions, without compromising the soft tissue results of the patients.

DECLARATION:

I declare that *Soft tissue profile changes in patients treated with non-extraction versus second premolar extraction protocols - using the Damon system* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full Name: Johan Christian Julyan **Date:** January 2018

Signed: ……………………………

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To my parents, for the way they raised me, their support and for motivating me to always aim higher.

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DEFINITION OF TERMS

Holdaway Analysis

A cephalometric analysis developed by Dr Reed A. Holdaway in 1983 that quantitatively express soft tissue relationships of patients that are considered pleasing and harmonious, as well as relationships that are not.

Self-Ligating brackets

Orthodontic brackets that have the ability to keep the archwire in the bracket, without the need for normal forms of ligation. The brackets have slots that close when the archwire is inserted into the bracket.

Damon system

A self –ligating bracket system with broad archwires, developed by Dr Dwight Damon in the 1990s. The Damon brackets have a twin configuration and a passive slide on the front of the bracket, designed to function like a tube.

Extraction Treatment

The removal of teeth to create space for resolving dental crowding with the use of orthodontic treatment.

Non-Extraction Treatment

Orthodontic treatment where no teeth are removed. Expansion of the dental arches, proximal stripping and molar distalization are used to create the space necessary to resolve dental crowding

Cephalometric radiograph

A diagnostic extra-oral radiograph, taken of the profile of the patient, to assess the positions of the jaws and teeth. The radiograph is also used to do tracings for orthodontic treatment planning.

CHAPTER 1

INTRODUCTION

One of the objectives of orthodontic treatment is to align teeth. Other equally important objectives include: the stability of the dentition, the perfect balance of facial aesthetics and the overall health of the oral tissues (Conte *et al*. 2001).

Successful orthodontic treatment often requires the removal of teeth in order to create space for the alignment of the remaining teeth. The removal of teeth is determined by the type of malocclusion, the amount of crowding, the soft tissue profile and the mechanics of treatment necessary.

It has become popular to remove second premolars in cases where the patient has a flat or harmonious profile, since the anterior teeth can be controlled well, and this technique doesn't have a severe effect on the facial aesthetics of the patient (Conte *et al*. 2001).

This study evaluated the soft tissue changes that occurred in patients treated with second premolar extractions and these patients were compared to patients treated with a non-extraction protocol.

Lateral cephalometric radiographs were used to evaluate the effect that treatment had on the soft tissues in both groups and to analyze the differences between the groups. This should enable clinicians to make better decisions during treatment planning in the future.

A cephalometric soft tissue analysis was developed by Dr Reed A. Holdaway in 1983. Holdaway (1983) summarized his analysis as a method to quantitatively express the soft tissue relationships considered to be harmonious and pleasing, as well as those which are not. The Holdaway analysis was used to conduct this study since the focus revolved around possible changes occurring with regards to the soft tissues of patients involved in the study.

CHAPTER 2

LITERATURE REVIEW

2. Introduction

Orthodontics is a field of dentistry that treats malocclusions in order to improve the function and aesthetics of patients (Aniruddh *et al*. 2016). Orthodontic treatment continues to evolve, and during recent years has brought on an increased interest and awareness of facial aesthetics linked to orthodontic treatment (Conley and Jernigan 2006). As stated by Janson *et al.* (2016), facial aesthetics plays an important role as one of the primary goals of orthodontic treatment.

Dr Edward Angle, the father of modern orthodontics, had paramount orthodontic treatment goals, which included facial beauty and harmony (James 1998). Angle developed the profile "line of harmony" from his studies, and believed a full complement of teeth would be able to best establish the necessary harmony (Angle 1900; Angle 1907).

Contemporary orthodontics places emphasis on the facial appearance of patients at the completion of treatment, as this is extremely important when evaluating the success of the treatment. (Peck *et al*. 1991). Patients tend to be more concerned with the dental aesthetic outcome of the orthodontic treatment, as well as their facial appearance rather than the actual benefit of an improved function.

In order to accurately assess the aesthetics of any patient, it is important to understand how the soft tissue profile can be influenced by orthodontic treatment. Capelli and Tibana (2002) stated that several studies have aimed to assess the soft tissue profile resulting from orthodontic treatment.

This is because the improvement of facial aesthetics is one of the main reasons for patients seeking to undergo orthodontic treatment.
Orthodontic treatment has the ability to influence soft tissues of patients, but the magnitude of changes that can occur is still being debated (Allgayer *et al*. 2011).

Facial profile evaluation is a constant learning process and has been extensively studied (James 1998). According to Allgayer *et al*. (2011) soft tissue and orthodontics continues to be an extremely important field of study. Orthodontists are often asked about the possible profile changes that can be caused by certain treatment plans.

Holdaway (1983) is among the scholars who have placed emphasis on the importance of looking at the soft tissues as part of the diagnostic process. He went on to develop a soft tissue cephalometric analysis after studying facial balance.

Quite often in orthodontic treatment there is a need to extract teeth in order to create the space necessary for treating the malocclusion. According to Aniruddh *et al*. (2016) there is no other aspect of orthodontics that has had more controversy than the extraction vs non-extraction debate.

The fact that extractions may result in a “flat face”, have discouraged this treatment protocol for various cases (James 1998). According to Janson *et al*. (2016), the speculation that exists around extractions and the creation of “dished in” profiles, are based on the assumption that a reduction in dental volume will result in a reduction of lip support. Downs (1948), believed that many cases require extraction of teeth to best restore and maintain balance and harmony of the face. The study conducted by Lim *et al*. (2008), agrees with the views of Downs and concluded that there exist many indications for extractions in orthodontics. These include: severe crowding, excessive protrusion and camouflage to treat skeletal discrepancies. Janson *et al*. (2007) further motivated the views of Downs by stating that the use of extractions can lead to an improved profile when properly indicated.

Extractions in orthodontics can involve different types of teeth, of which the premolars are the most popular. Cases involving the removal of premolars for orthodontic treatment can involve the removal of either first or second premolars. (Mascarenhas *et al*. 2015).

Wholley and Woods (2003) mentioned that whether or not the removal of premolars possesses the potential to produce adverse effects on the soft tissues of treated patients remains controversial. Cited in the article by Wholley and Woods (2003), the potential for premolars to cause adverse soft tissue effects have been debated for more than a hundred years, with Nance, in 1947, already stating that extraction cases had become synonymous with the removal of four first premolars. He also later suggested the removal of the four second premolars as this will have even less influence on the facial profile of patients.

As cited in the article by Mascarenhas *et al*. (2015), the removal of the second premolars seems to be the popular choice in cases with moderate crowding, acceptable facial profiles and good incisor positions.

A very noticeable trend towards more non-extraction treatment has been seen over the past two decades (Rinchuse *et al*. 2014). Non-extraction treatment does not involve the removal of any teeth for treatment purposes, and is favored by the patients. The Damon system, one of the orthodontic techniques used nowadays, gets marketed as a technique where almost all cases can be treated without any extractions. The Damon system is a self-ligating bracket system with a twin configuration that is manufactured to function as a tube. The system makes use of broad Copper Nickel Titanium arch wires to expand the dental arches enough so that extractions are not necessary.

The constant change in opinion with regards to extraction and non-extraction treatment protocols, as well as the non-extraction "at all cost" philosophy, were the most important motivating factors for conducting this study.

2.1 Orthodontic treatment

Orthodontics is the discipline of dentistry that treats dentofacial deformities and malocclusion to ultimately improve function and aesthetics (Aniruddh *et al*. 2016). Orthodontic treatment can either be fixed or removable, and various appliance systems exist that can aid in the treatment of malocclusions.

The mechanics available for orthodontic treatment have become more effective, which further contributes to the increased importance of soft tissues in the diagnosis and treatment outcomes (Allgayer *et al*. 2011). According to Khan and Fida (2010), it is well accepted that orthodontic treatment can have an effect on the facial soft tissues and proportions of patients that undergo treatment. There exists an agreement that orthodontic treatment has the ability to influence the soft tissues of patients, but there is still disagreement regarding the magnitude of the soft tissue changes (Allgayer *et al*. 2011).

Riedel (1950) stated that orthodontic treatment should always place emphasis on the facial aesthetics of patients since this aspect is one of the major motivating factors for patients seeking treatment. According to Conte *et al*. (2001), occlusal harmony and facial balance should be the main objective of the orthodontic speciality. According to Peck *et al*. (1991), contemporary orthodontics requires an acceptable facial appearance at the completion of treatment. Current trends in orthodontic treatment strive for fuller profiles and fuller lips in order to create a more youthful appearance (Erbay and Caniklioglu 2002). As stated by Darendeliler and Taner (2006), the success associated with orthodontic treatment is closely associated to favourable changes in the facial soft tissues of the patients. An accurate and detailed assessment of the facial profile of all patients seeking orthodontic treatment should be part of the diagnosis and treatment planning (Holdaway 1983).

The decision whether or not to extract teeth remains the most critical decision that orthodontists have to make when formulating a treatment plan (Baumrind *et al*. 1996). Various techniques exist for treating malocclusion.

This involves the decision on whether or not teeth need to be removed, in order to obtain the necessary space for successful orthodontic treatment.

2.2 Extraction versus Non-Extraction

There are two different approaches that can be conducted when treating severe malocclusions. Extraction, the first of the two approaches, possesses the ability to resolve dental crowding, correct protruding teeth, as well as improve facial profiles. Non-extraction, the second of the two approaches, required the expansion of the dental arches, as well as proximal stripping and molar distalisation, all in an effort to create the space necessary to resolve dental crowding (Aniruddh *et al*. 2016).

For more than a hundred years the debate regarding the extraction of teeth for orthodontic treatment has been present (Kocadereli 2002). According to Aniruddh *et al*. (2016) there is most likely no other aspect in orthodontics that has caused as much controversy as the extraction versus non-extraction decision. The debate regarding extraction and non-extraction has started as early as the beginning of the 20^{th} century. The first to advocate non-extraction, being the father of modern orthodontics, Dr Edward Angle, who suggested that all 32 teeth can be aligned without the need for dental extractions (Rinchuse *et al*. 2014).

A 1911 National Dental Association meeting saw Dr Calvin Case argue the necessity for extracting teeth in some cases against the non-extraction “at all cost” protocol that Dr Martin Dewey promoted (Rinchuse *et al*. 2014). At the mentioned debate, the beliefs of Dewey prevailed, and subsequently resulted in extractions falling out of favour (Wahl 2005).

An AAO meeting in 1944 in Chicago, saw Dr Charles Tweed describe retreatment of 300 of his previously failed non-extraction cases, with the removal of teeth, which he claimed to have an improved stability (Brandt 1968).

This description of Dr Tweed resulted in a rise in extraction rates, which saw a peak in the 1960s to 75%. This again declined in the 1980's and in the 1990's only 15-20% of cases were treated with the use of extractions (Rinchuse *et al*. 2014).

According to the article by Rinchuse *et al*. (2014), a very noticeable trend towards more non-extraction treatment has been seen over the past two decades. Proffit indicated that the recent decline in the frequency of extractions, is a result of changes in techniques, concerns regarding facial aesthetics, as well as stability and the possibility of temporomandibular dysfunction (Proffit 1994).

As stated by Saelens and De Smit (1998), when non-extraction treatment is performed without the use of extra-oral traction, the assumption is made that the alignment of the teeth results in proclination of the anterior teeth, as well as the facial profile of the patient. According to Mascarenhas *et al*. (2015), the selection of which teeth to be extracted for orthodontic treatment is a very important decision and should be modified according to each individual patient.

The decision of which teeth should be extracted is quite difficult. Any clinician should first establish which teeth, if extracted, will have the least effect on the profile of the patient (Dewel 1955). The decision on whether to extract teeth should be made by not only considering the amount of dental crowding, but also by the expected influence on the soft tissue profile of the patients face (Saelens and De Smit 1998).

According to Kocadereli (2002), the facial profile effects associated with extraction and non-extraction in orthodontic treatment have been of great concern for orthodontists. The effect of extractions on the facial profile has always been the major issue regarding the decision of extraction versus non-extraction.

The non-extractionists continue to argue that extractions in orthodontic treatment results in a "dishing in" of the facial profile, whereas extractionists are concerned with the stability of the profile being too full and effect on periodontal health in non-extraction cases (Burrow 2008; Yared *et al*. 2006; Dorfman 1978; Artun and Krogstad 1987).

According to Gianelly (2003) and Paquette *et al*. (1992), extractions in orthodontic treatment have been criticized for resulting in narrower dental arches, as well as the formation of dark corners that can have an undesirable effect on smile esthetics. The studies of Bishara *et al*. (1994) and (1997) have supported the flattening effect on the facial profile by extracting teeth for orthodontic treatment whereas the study of Luppanapornlap and Johnston (1993) have not supported it.

The "at all costs" non-extraction protocols should be questioned to ensure that the public and dental profession are not misled. Kandasamy and Woods (2005) mention in their study that the distalization of molars, to ensure enough space to align the anterior teeth, and to avoid premolar extractions, has the tendency to create a space deficiency in the posterior part of the mouth. This deficiency affects the eruption of the second and third molars. According to Kandasamy and Woods (2005), quite often the forced non-extraction approach can lead to the impaction and subsequent extraction of third molars in the future.

In general authors that publish regarding the facial profile effects of extractions, agree that no dishing in of the face occurs, and that this contribute to more pleasing esthetic results, when compared to the fuller profiles produced by non-extraction treatment (Rinchuse *et al*. 2014).

According to Bishara *et al.* (1995), when the decision, whether to extract or not, is made from proper diagnosis, there seems to be no negative effects on the soft tissue profile of the patients being treated, and according to Proffit (2000) almost one third of malocclusions warrant the need for extractions based on their severity.

As cited in the article by Khan and Fida (2010), similar observations have been made by other authors that the removal of teeth doesn't influence the facial profile of patients when the treatment decision has been made after proper diagnosis.
A study that agrees with that of Konstantonis (2012) is that of Aniruddh *et al*. (2016). The results of this study were that class I cases treated with extractions resulted in upper and lower lip retraction, as well as an increase in the upper lip thickness that proved to be significant. Other observations in the extraction group also included a more obtuse nasolabial angle, a similar observation than that of Konstantonis (2012).

Concluded in the study by Saelens and De Smit (1998), was that with the appropriate indications, both the removal of first or second premolars or non-extraction treatment results in good occlusal, and no unfavorable facial profile changes.

Ismail and Moss (2002) examined three dimensional effects of extraction and non-extraction treatments in their study and concluded that the effects of the two types of treatment on facial soft tissues were very similar. The study conducted by James (1998), compared the facial profile of extraction and non-extraction treatment groups and found the measurement averages to all be within the normal range at the end of treatment.

In recent times a non-extraction, at all cost, treatment approach has become popular, and it seems that the information received by the public is that clinicians, who make use of extractions to align teeth, are old fashioned and providing a disservice to their patients (Kandasamy and Woods 2005).

According to Richardson (1975), a group of patients studied by him that had been treated without any extractions in the mandible, had eventual third molar impactions in 56% of the cases.

According to Kandasamy and Woods (2005), less emphasis should be placed on treating every patient without extractions, but rather to address each patient as an individual, with his/her own set of dentofacial problems. Extraction and non-extraction techniques should be seen as different options to best treat the diagnostic needs of each and every patient.

Although extractions are widely accepted in orthodontics, it remains an important decision whether or not to remove teeth for orthodontic treatment and it is something that needs to be modified for each individual patient (Mascarenhas *et al*. 2015).

From the literature it seems clear that no definite decision has been made regarding extraction and non-extraction treatment. Various studies compared the treatment effects of extractions and non-extraction cases. The majority of the studies conclude that no significant soft tissue changes occur in either treatment approach, yet a large group of authors still feel that dished in profiles are caused by orthodontic treatment in accordance with extractions.

The constant debate regarding extractions, as well as the introduction of the Damon system, motivated the writer to further contribute to the literature by comparing the results of second premolar extraction and non-extraction cases after treatment using the Holdaway cephalometric soft tissue analysis.

2.3 Premolar extractions

The most commonly extracted teeth for orthodontic purposes are the premolars. Their location, situated between the anterior and posterior segments of the mouth, make them a convenient option for extraction (Shearn and Woods 2000). According to the study by Hans *et al*. (2006), the teeth most commonly extracted for orthodontic treatment are the premolars. The premolars are normally removed to create space to resolve dental crowding or to treat cases with bimaxillary protrusion (Kumari and Fida 2010).

Removal of premolars, to resolve malocclusion with orthodontic treatment, is a common procedure and in these cases either the first or second premolars are removed (Mascarenhas *et al*. 2015).

Proffit (1994) after analyzing data from the University of North Carolina, found that the decision regarding extractions for orthodontic treatment was only related to cases where the four first premolars were removed.
There is a common belief that premolar extractions result in dishing in of the face and that it can lead to premature aging of the face (Khan and Fida 2010).
According to Luppanapornlarp and Johnston (1993), extraction of four premolars for orthodontic treatment tends to flatten the facial profile of patients by 2-3 mm when compared so similar non-extraction cases.

According to Witzig and Spahl (1986), the extraction of premolars for orthodontic treatment has been condemned due to the alleged detrimental effect that it can have on the facial aesthetics of the patient.

Many dentists and orthodontists use the alleged detrimental effects on facial aesthetics to justify their decisions to not extract teeth in patients where there is a space shortage. Their belief that premolar extractions result in flat facial profiles, results in their avoidance to remove premolars for orthodontic treatment (Boley *et al*. 1998). Numerous authors have provided the results to show that the fear of flattening the facial profile with premolar extractions, is unfounded.

According to Kachiwala *et al*. (2009), the potential of premolar extractions to cause soft tissue profile changes after orthodontic treatment, still remains controversial. Williams and Hosila (1976) found that the extraction of premolars in orthodontic treatment results in soft tissue profile changes. Some cases result in improved aesthetics and others in undesirable outcomes.

The study by Boley *et al*. (1998) concluded that the removal of premolars for orthodontic treatment is still a valuable option in the treatment of appropriate cases.

According to Drobocky and Smith (1989), 90% of patients that received orthodontic treatment with extraction of four premolars, had improved or maintained facial profile aesthetics after treatment, when the hard and soft tissues were measured.

Paquette *et al*. (1992) also found that patients treated with or without extractions of premolars both presented with similar aesthetic results. Bishara and Jakobsen (1997), in the general population study, compared extraction and non-extraction groups both after treatment and after two years of the cessation of treatment, and found the same results for both groups.

In the studies by Luecke and Johnston (1992) and McLaughlin and Bennett (1995), it has been indicated that the statement that premolar extraction can lead to undesirable or flat facial profiles, has no basis. Drobocky and Smith (1989) and Young and Smith (1993) declared that it is incorrect to blame premolar extractions for unfavorable facial esthetics after orthodontic treatment.

In the study by Saelens and De Smit (1998), where the removal of premolars was compared to non-extraction treatment. The molars moved mesially and the lower incisors remained in more or less the same antero-posterior position, compared to the non-extraction group where the lower anterior teeth became proclined with orthodontic treatment. To avoid premolar extractions, based on the possible detrimental effect that it might have on the soft tissue profile, was found to be unjustified in the study conducted by Darendeliler and Taner (2006).

The results of the study by Steyn *et al*. (1997), suggest that the choice of which premolars are extracted for orthodontic treatment will have virtually no effect on the patient's soft tissue after treatment. Unfortunately, two treatment approaches cannot be tested on the same patient at the same time (Steyn *et al*. 1997).

Regression models were used by the authors of Steyn *et al*. (1997), and they tested their formulas against 18 randomly selected patients from their study, which ended up showing that only one or two-millimetre difference can be expected when any of the three premolar extraction choices are made. The study done by Steyn *et al*. (1997), showed conclusively that whether first or second premolars are extracted, the soft tissue appearance that the patient exhibits after treatment will be virtually the same, provided that all other aspects remain constant.

In a study done by Bravo (1994), 16 patients treated with extractions of four premolars were examined and 12% found to have finished with a more retrusive profile. They also argued that if stricter guidelines were used to evaluate the numbers, the percentage of flattened profiles could have gone to 62%.

Premolar extractions have also been shown to have other advantages. Selected cases where premolars were extracted were found to have a higher percentage of successful eruption of the third molars, when compared to non-extraction cases (Sable and Woods 2004). According to Kandasamy and Woods (2005), premolar extractions, when chosen after proper diagnosis, has the potential to provide increased space to aid the eruption of third molars.

Ricketts (1972), reported a 25% average increase in space available for third molars when he examined cases where premolars were extracted. He also found there to be a 45% chance of third molar extractions being necessary when he looked at cases treated without the extraction of any premolars. However, he also noted a 15-20 % chance of third molar extractions being necessary, even with premolar extractions present.

2.4 Second Premolar Extraction

Nance published in (1941) a study where he treated a case with congenitally missing second premolars and expressed his opinion that extracting second premolars can be a viable treatment option.

After the study and statement, he continued to recommend that in many cases the extraction of second premolars should take preference above the extraction of first premolars. Nance (1941), also mentioned that there are several cases he has treated with the removal of first premolars, but if he could have repeated them, he would make use of second premolar extractions instead. Nance (1941) drawing from evidence in his own practice mentioned how spaces did not reappear, and acceptable stability was seen in the cases treated with second premolar extractions.

Schoppe (1964) who also studied cases treated by second premolar extractions, concluded that more controlled mesial movement of the molars can be achieved while keeping them in in a good inclination.

Steadman (1964) while discussing Schoppe's article made the observation that extraction of second premolars made space closure easier and allowed the teeth to remain synchronized with the growth of the soft tissues and the profile. Schwab (1971), made the discovery that the maxillary and mandibular incisors required less retraction when the second premolars are extracted for orthodontic treatment. The authors of the article by Conte *et al*. (2001), drew their conclusion after an extensive literature review, that second premolar extractions result in nil or reduced incisor retraction, with the same effects on the lips.

Non-extraction treatment has become more popular with the introduction of different orthodontic appliances and techniques for distalising the molars according to Khan and Fida (2010), but in cases where extractions are necessary, the removal of second premolars is a good alternative. According to the studies by Schwab (1971), Schoppe (1964) and DeCastro (1974), cases with acceptable facial profiles and incisor positions and that have mild crowding, are good candidates for the removal of second premolars. De Castro (1974) recommends the removal of second premolars in cases where the retraction of anterior teeth should be avoided.

He specifies further that the closing of the extraction spaces will be accomplished by the mesial movement of the posterior teeth and not through retraction of the anterior teeth.

The removal of four second premolars can be used in conjunction with fixed orthodontic treatment in the following instances (Mascarenhas *et al*. 2015):

1. Mild to moderate space shortage anterior
2. No need for profile changes

Mascarenhas *et al.* (2015) showed numerous advantages in their study for the removal of second premolars:

1. Minimal increase in overbite and curve of Spee
2. Easy maintenance of the lower incisor position
3. Limited lingual movement of the lower anterior segment.
4. They have also shown that normal lip support and facial profile can be maintained when the residual extraction spaces are carefully managed during treatment.

Generally, more mesial movement of the molars and less retraction of the incisors is seen with second premolar extractions compared to the extraction of first premolars (Shearn and Woods 2000).

Dewel (1955), Logan (1973) and Nance (1949), all recognized that second premolar extractions are advantageous and that it not only aids rapid closure of spaces but also maintains good marginal relationships between the mandibular first molar contact points. Salzmann (1945) advocates the use of second premolar extractions when the objectives include mesial movement of the molars and tooth alignment. De Castro (1974) in his study mentioned that only the posterior segment of the mouth is affected when second premolars are extracted.

Proffit (1993), made use of clinical observation to quantify the expected anterior teeth retraction and mesial movement of posterior teeth, between different extraction patterns. He came to the conclusion that the further posterior the extractions are, the less the retraction on the anterior teeth will be. He also mentioned that even with second premolar extractions, there will be retraction of the anterior teeth, but the majority of space closure will be through mesial movement of the molars.

Chen *et al*. (2010b), conducted a study to evaluate the moving patterns and changes of position of incisors and molars in patients treated with the extraction of four second premolars. Cases evaluated were all Angle Class I, with mild crowding and dental protrusion. They concluded that the space created by the extractions was almost equally closed by the remaining anterior and posterior segments. The first molars moved mesially by 3.2 mm in the maxilla and 3.4 mm in the mandible on average. The incisors moved lingually on average 3.3 mm in the maxilla and 2.9 mm in the mandible.

Second premolar extractions seem to result in a greater intermolar width reduction following treatment than first premolar extractions (Ong and Woods 2001) According to Mascarenhas *et al*. (2015), the extraction of second premolars definitely has benefits, which include the limited lingual migration of the mandibular anterior teeth, minimal increase in curve of Spee and minimal increase in overbite.

<u>The extraction of second premolars is seen as beneficial for both occlusion and aesthetics, due to the following reasons:</u>

- The mesiodistal width of the maxillary first premolars are larger than the second premolars, this aids the more distal placement of the maxillary first molars compared to the lower first molars after treatment (Schudy 1992).

- The maxillary first premolars offer more resistance to lateral stresses, due to them having two roots that are longer and more divergent than that of the maxillary second premolars (Schudy 1992).
- The buccal cusp of the maxillary first premolar is longer than that of the second premolar, which helps with disarticulation of the molars during lateral excursions (Conte *et al*. 2001). The longer cusp blends better aesthetically with the maxillary canine (Begg and Kesling 1971). The longer buccal cusp of the maxillary first premolar occludes mesially with the mandibular first molar, resulting in better dental interlocking (Logan 1973; Schudy 1992).
- The mandibular second premolar has a larger mesiodistal width compared to the mandibular first premolar, which after its extraction, makes mesial movement of the mandibular molar easier (Schudy 1992).
- When the second premolars are extracted, the dentition is more stable, because the remaining teeth's cusps require less manipulation and movement. The canines also require less movement, and less inadvertent expansion occurs (Schoppe 1964).
- The contact between the maxillary first and the mandibular first premolars, tend to remain tight. The tendency for extraction spaces to reopen is minimized if the lateral dental inclinations are correct after treatment (Logan 1973; Schoppe 1964).
- Extraction of second premolars facilitate the closure of anterior open bites, since their removal reduces the posterior vertical dimension (Logan 1973).

<u>The following guidelines have been developed for second premolar extractions:</u>

- Cases exhibiting a Class I or mild Class II malocclusion, with minimal crowding, acceptable profiles and if hyperdivergent (Begg and Kesling 1971).
- Bimaxillary protrusive cases with slight crowding (Begg and Kesling 1971).
- Cases with second premolar agenesis or morphological crown anomalies (Begg and Kesling 1971).

- Cases with crowding between 2.5 mm and 5 mm (Carey 1952; Schwab 1971).
- Cases with moderate crowding and a flat profile (Begg and Kesling 1971).
- Cases with slight Class III and minimal crowding present (Begg and Kesling 1971).

Second premolar extraction is the preferred choice in patients that exhibit mild to moderate crowding, acceptable incisor positions and acceptable soft tissue facial profiles (Mascarenhas *et al*. 2015).

Conte *et al*. (2001), concluded from their study using two case reports, that the choice to extract second premolars should be made only after proper diagnosis and accurate evaluation of the treatment plan considered. Mesial movement of molars and less labial movement of the incisors occur with second premolar extractions. This option has insignificant effects on the profile of the patient and allows extraction spaces to remain stable, provided that there is good dental inclination.

2.5 Soft tissue profile effects in premolar extractions

According to Boley *et al*. (1998), the effect that orthodontic treatment can have on the patient's face should be one of the major concerns of any orthodontist. Most orthodontists are convinced that the soft tissue profile is influenced by orthodontic treatment, however, controversy exists regarding the precise response of the soft tissue, when teeth are moved into different positions (Saelens and De Smit 1998).

The changes of the soft tissue profile have long been recognized by orthodontists. At times these changes can result in the soft tissue profile improving, therefore justifying, the extractions, whereas other times, flattening of the profile occurs when premolars are extracted (Drobocky and Smith 1989).

According to Erbay and Caniklioglu (2002), orthodontic treatment affects the facial proportions of patients and it is generally accepted that fuller, more prominent lips, leads to a more youthful appearance.

According to Proffit (1994), a decline has occurred in the frequency of extractions due to the changes in techniques, temporomandibular dysfunction, stability and the major concern regarding facial aesthetics.

As cited in the article by Wholley and Woods (2003), various soft tissue assessment lines have been developed over the years of which include: Ricketts E-line, Steiner's S-line and Merrifield's Z-angle. These lines are commonly drawn on cephalometric radiographs and can be used for orthodontic treatment planning. Facial thirds, chin prominence, upper lip curl, profile line relationship and lower lip posture, are regarded to be the 5 common measurements used to evaluate harmony and beauty of the face and profile (James 1998).

A question arising from the literature is whether premolar extractions can be done without any significant effect on the soft tissue profile of the patients (Khan and Fida 2010).

According to Luppanapornlarp and Johnston (1993) the removal of four premolars with orthodontic treatment generally results in a 2-3mm flattening of the facial profile when compared to that of non-extraction cases. Another example of this is reflected in the common belief that when premolars are removed for orthodontic treatment, a dishing in of the facial profile occurs, which results in premature aging of the face (Khan and Fida 2010).

The results of the study by Khan and Fida (2010), showed no significant difference in the lip position when comparing extraction and non-extraction cases. This proved that the soft tissue characteristics remained the same for the two treatment groups.

The statement was motivated by the fact that the patients treated with extractions finished within the same soft tissue parameters as those treated without extractions. This concluded that premolar extractions do not negatively influence the soft tissue profile of patients.

Young and Smith (1993), as well as Luppanapornlap and Johnston (1993), compared in their studies, the facial effects caused in general, by the extraction of teeth and those where no teeth were removed. They found that it is incorrect to contribute any undesired facial aesthetics caused by orthodontic treatment, to the removal of premolars exclusively.

In the study by Allgayer *et al*. (2011), the Holdaway analysis was used to determine the facial profile influence on the patients treated with premolar extractions. The study's conclusion agrees with that of Khan and Fida (2010) in that the facial profiles were very similar after treatment with various extraction protocols used.

The study done by Konstantonis (2012), where Class I cases that underwent extraction or non-extraction treatment were compared, the following results were found: The extraction group finished the orthodontic treatment with a more obtuse nasolabial angle, more retracted lips and a thicker upper lip. The non-extraction group showed lower lip protraction and significant upper lip retraction after treatment commenced. The results of the study by Konstantonis (2012) disagrees with that of Khan and Fida (2010) as well as Allgayer *et al.* (2011).

The study by Kocadereli (2002), where pre- and post-treatment cephalograms of Class I patients treated with or without premolar extractions were assessed, showed more retruded upper and lower lips in the patients that had extractions. Bishara *et al*. (1997), also made the statement that extraction and non-extraction treatment does not have a detrimental effect on the facial profile after treatment.

The results of the study by Wholley and Woods (2003) concluded that it is not the routine outcome for patients treated with premolar extractions to have adverse facial profile changes, and that the lateral facial profile can be protected if extraction spaces are managed correctly.

Boley *et al*. (1998) did a study to determine whether there was any difference between faces of patients treated without extractions and those treated with extractions of premolars. Both the perceptions of dentists and orthodontists were used to conduct their research. Participants were asked to look at photos of patients that received orthodontic treatment. Some patients were treated without extractions and others with premolar extractions. They had to identify the patients that were treated with extractions and those without. The mean score of the study showed results that were just slightly better than pure chance, by ending in a 54% success rate. The same authors, Boley *et al*. (1998), conducted a study by doing cephalometric tracings for both the extraction and non-extraction groups and found that no significant differences exist, thereby proving that the fear of having a detrimental effect on the facial profile of patients, with premolar extractions, is unjustified, provided that the patients are properly diagnosed and treated.

The study conducted by Boley *et al*. (1998) found that soft tissue profiles became straighter during orthodontic treatment in both extraction and non-extraction groups. Findings from studies done by Rushing *et al.* (1995), as well as Johnson and Smith (1995), also found no significant difference when comparing the faces of extraction and premolar extraction patients after orthodontic treatment.
When cases are properly diagnosed and planned, with the necessary anchorage requirements, practitioners should not see any unfavorable effects of the facial profile due to over-retracting the anterior teeth (Paquette *et al.* 1992).

According to the study done by Allgayer *et al.* (2011), the results of the facial profiles of the patients after treatment, were similar when using the Holdaway soft tissue analysis.

The study by Khan and Fida (2010), compared extraction and non-extraction cases and found that the effects caused by the two types of treatment on the facial soft tissues were similar. This was an indication that premolar extraction does not have an undesirable effect of facial aesthetics, provided that the mechanics of the treatment is controlled well and the decision to extract is made on a sound basis.

One should always remember that both treatment and growth influences the changes in facial profiles of patients. The growth of the chin and nose continue to change from adolescence and throughout life (Shearn and Woods 2000). Undesirable soft tissue changes are often not as a result of previous orthodontic treatment, but the result of the normal physiological development of the patient (Darendeliler and Taner 2006). Soft tissue profiles tend to straighten with an increase in age due to the continued growth of the mandible, irrespective of which treatment modality was used (Bjork 1969) and even throughout adulthood the face does have the tendency to flatten (Behrents 1984).

Mc Laughlin and Bennett (1995) pointed out in their study that the facial profile might become flattened, irrespective of whether teeth were extracted or not. A patient with a retruded dentition with reference to the chin and nose will normally develop a flattened profile even with non-extraction treatment.

It is important for orthodontists to be aware of the soft tissue profile changes caused by adolescence and post-pubertal growth, and to not only focus on what can be caused by orthodontic treatment (Timothy and Peter 1997). However, the evaluation of facial balance, as well as facial profile changes continues to be a major learning process for orthodontists (Kocadereli 2002).

2.6 Self - ligating brackets

Self-ligating brackets are brackets that do not require the normal forms of ligation to keep the arch wire in the bracket. The brackets are manufactured with a slot that closes when the arch wire is inserted into the bracket.

Self-ligating brackets were first pioneered in the 1930's and have undergone revival the past 30 years, with various different appliances developed (Fleming and Johal 2010).

Many claims have been made regarding the ability of self-ligating brackets to reduce treatment time, improve effectiveness, as well as avoid any necessity for extracting teeth in most cases (Rinchuse *et al*. 2014). Self-ligating brackets have been proven to have the advantage of decreased treatment time and a decrease in the amount of appointments required for the patients receiving treatment (Fleming and Johal 2010).

The time necessary to change the arch wires is decreased with self-ligating brackets and patients only need to see their orthodontists every 8 weeks, because of the absence of normal ligation materials that tend to lose their force after 4 weeks.

Evidence based research conducted showed self-ligating brackets to only be more beneficial than conventional brackets with regards to the control of mandibular incisor proclination (Marshall *et al*. 2010 and Chen *et al*. 2010a).

According to the systematic review done by Fleming and Johal (2010), they found insufficient evidence supporting the use of self-ligating brackets over the conventional orthodontic brackets. They also could not find compelling evidence that orthodontic treatment is more or less efficient when self-ligating brackets are being used.

One of the most popular self-ligating brackets, are the Damon system brackets. These brackets were developed by Dr Dwight Damon and are currently a popular option when it comes to self-ligation brackets.

2.7 Damon orthodontic system/technique

Dr Dwight Damon, in the 1990s, developed the theory that low friction and light forces will lead to more biologically stable orthodontic results. He subsequently developed the Damon orthodontic system.

The Damon system is composed of self-ligating brackets with broad arch wires. The brackets have a twin configuration, as well as a passive slide on the front of the bracket (Vajaria *et al*. 2011).

The design of the Damon bracket is to function like a tube, with a static facial wall, making it self-ligating and allowing it to function as a passive appliance that can achieve physiological forces.

According to studies by Damon (1998a), Voudouris (1997), Pizzoni *et al*. (1998) and Kim *et al.* (2008), less friction is exhibited by self-ligating brackets during sliding mechanics when compared to conventional brackets. The Damon system in particular produce less friction when compared to ligated brackets.

In 1995 the first Damon bracket was introduced. The bracket was used in conjunction with changes in arch wires and sequences. Dr Damon advocates the use of Copper Nickel Titanium arch wires as the initial wires that produce a light force and that are wider than conventional arch wires (Damon 1998a).

The Damon philosophy states that the arch form aligns by taking the path of least resistance, which in this case is through posterior expansion (Pandis *et al*. 2007; Damon 1998b).

Dr Dwight Damon suggests that treatment plans of patients should focus on the profile, arch width and the general facial support.

According to the study by Vajaria *et al*. (2011), Damon believes that the mandibular intercanine width does not change significantly when using the Damon system. He also shows minimal labial movement of the incisors in his studies using lateral cephalometric tracings.

The philosophy of the Damon technique is to only make use of the minimum or threshold force required to initiate movement of teeth (Damon 2004). The Damon system makes use of a combination of super elastic nickel titanium archwires and passive self-ligation, in order to achieve the small forces. The system is designed to produce an environment of low force-low friction, which will ensure efficient tooth movement by making sure that teeth remain within a zone of optimal force throughout treatment (Damon 1998a).

The Damon theory is based upon the premise that the low orthodontic forces will help to maintain the patency of the periodontal ligament blood vessels. This will in turn facilitate a maximum cellular remodelling during the tooth movement (Krishnan and Davidovitch 2006). The light forces used by the Damon system are preferred due to their ability to induce frontal resorption rather than undermining resorption and hyalinization (Krishnan and Davidovitch 2006).

A claim made by Dr. Damon is that the zone of optimal force created during treatment will allow for physiological adaptation to occur. It is, therefore, claimed that the orofacial muscles and periodontium are never overpowered and allows connective tissue and the alveolar bone to move with the teeth during treatment. This claim is still very controversial since it represents a shift from the conventional orthodontic thinking (Peck 2008).

Damon (1998b), summarised the advantages of his Damon low friction bracket as being:

- Greater control that improves quality of treatment.
- Improvement in patient comfort during treatment.
- Decreased treatment time due to faster alignment and less time required for finishing.
- Decreased amount of appointments.
- Decrease in chair time during appointments.
- Improved treatment planning options.

- Simplification of treatment mechanics necessary.
- Easier oral hygiene practices.
- Improved work environment for auxiliaries.
- Improved profitability and efficiency.
- Attraction of more adult patients seeking treatment.

According to Wright *et al*. (2011), there does exist some evidence that the use of the Damon System will lead to a reduction in chairside time for the orthodontist, but the claim that the Damon system will reduce the pain experienced by the patient, remains inconclusive.

When identical arch wire sequences are used there exists no evidence that the Damon System brackets can align teeth faster than conventional ligation brackets. There is also no high-quality evidence exists that the Damon System results in faster treatment, better occlusal and aesthetic results, and improved stability (Wright *et al*. 2011).

Claims have been made by Damon (2004) that the Damon orthodontic system produces wider and fuller smiles that enhances facial balance and aesthetics. Considerable expansion can be achieved posteriorly with using the Damon system, which produces a broadened arch that is in balance with the tongue and cheeks (Damon 2004).

Pandis *et al*. (2007) and Vajaria *et al.* (2011), found in their studies a greater increase in intermolar width when comparing patients treated with the Damon system to those treated with conventional edgewise appliances.

The authors of Shook *et al*. (2016) found the increase in arch width to occur in both groups, stating that both the Damon brackets and the conventional brackets produce the same amount of expansion.

2.8 Holdaway cephalometric analysis

The Holdaway analysis is a cephalometric analysis and was developed by Dr Reed A. Holdaway. This analysis attempts to quantitatively express soft tissue relationships that are considered pleasing and harmonious, as well as relationships that are not. The analysis can be used to differentiate between pleasing and unpleasing facial relationships. The information obtained from the analysis can then be used for orthodontic treatment planning (Holdaway 1983).

Soft tissue profile is a very important part when considering orthodontic treatment. Changes in soft tissues occur while treating malocclusions and should be pleasing to all concerned (Holdaway 1983).

According to Holdaway (1984), a treatment approach focused on soft tissues, would ultimately benefit both the doctors and patients more.

It is important to determine before orthodontic treatment, whether the treatment will benefit the soft tissue profile or result in adverse facial changes (Holdaway 1983).

If soft tissue features are quantitated, we can make use of these to better our treatment goals. Improved treatment goals for all patients is the primary reason for the development of this soft tissue analysis (Holdaway 1983).

Although Holdaway always had a special interest in facial balance, an excellent occlusion remained paramount. Holdaway defines his analysis as being a "Soft tissue approach to treatment planning" (Holdaway 1983). Holdaway, who spent time as an instructor in the Tweed course, obtained the necessary goals set out by Tweed in the cases treated, but still felt that 20 to 25 percent of the cases lacked the necessary harmony when facial lines were examined after treatment. Tweed made use of a diagnostic triangle as his treatment tool, but the limitations of this tool was later recognized by Tweed himself (Holdaway 1983).

The Holdaway analysis is a set of eleven measurements. The eleven measurements are made up of two angular and nine linear measurements.

Dr Reed A. Holdaway (1983) developed the eleven measurements that make up the Holdaway analysis and they are as follows:

The **H-line/Harmony line**, developed by Holdaway is a tangent drawn from the tip of the chin to the upper lip, and is used during the analysis for various measurements, see Figure 2.

1. **Soft-tissue facial angle**

The facial angle is an angular measurement formed by the intersection of a line drawn from the soft tissue nasion to the soft tissue pogonion, and the Frankfort horizontal plane, see Figure 1.

91 degrees is the ideal measurement. Range of ± 7 degrees is still seen as acceptable.

When the angle is greater it indicates a protrusive mandible and when the angle decreases below 90 degrees in indicates a retrusive mandible.

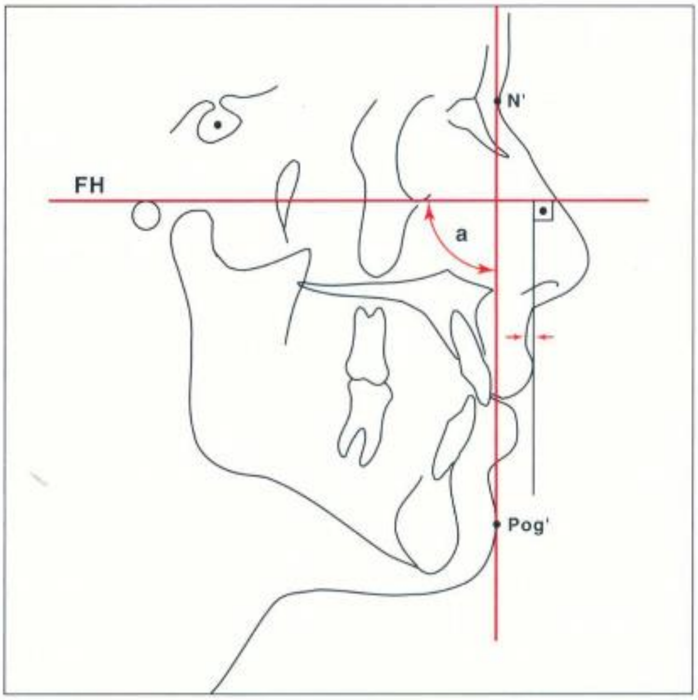
2. **Superior sulcus depth**

Measured from the upper lip sulcus to a line drawn perpendicular to the Frankfort horizontal that runs tangent to the vermilion border of the upper lip, See Figure 1.

For this measurement 3mm is the ideal, with a range of 1-4 mm considered acceptable. Patients with average thickness lips tend to have a measurement of 3mm. The measurement decreased in patients with thin lips and increases in patients with thick lips. Very small measurements can be indicative of lip strain and higher measurements suggest jaw overclosure or lip redundancy.

According to Holdaway (1983), we should aim to not let this measurement decrease to less than 1.5 mm during our orthodontic treatment.

Figure 1 - Soft tissue facial angle, superior sulcus depth (Jacobson 1995)



3. <u>Nasal Prominence</u>

The prominence of the nose is measured by means of the distance from the nose tip to a line drawn perpendicular to Frankfort horizontal that runs tangent to the vermilion border of the upper lip, see Figure 2.

A nasal prominence of less than 14 mm is considered small and when the measurement exceeds 24mm it falls in the prominent or larger range.

Nasal form and prominence should be judged for each individual but should, if possible, not be more than 12mm in individuals 14 years of age.

4. <u>Soft-tissue subnasale to H line</u>

Measured from the soft tissue subnasale to the H-line, see Figure 2.

The ideal measurement is 5mm. There is an acceptable range of 3mm to 7mm. Patients with short and thin lips can have an adequate measurement of 3mm and longer and thicker lips with measurements of 7mm are still considered acceptable.

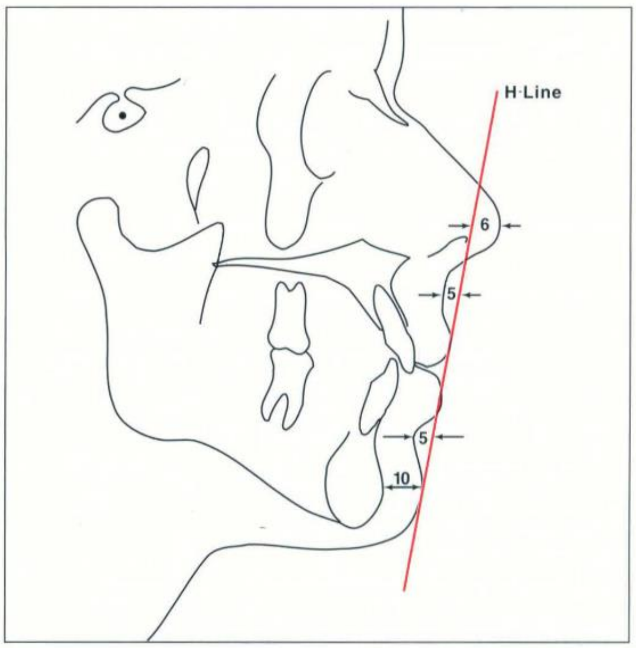
It is important to remember that cases which falls on either extreme of the skeletal convexity measurement, the ideal measurement to the H line will lose significance due to the change in the H-line's cant.

5. **<u>Inferior sulcus to the H-line</u>**

This measurement is made from the H-line to the deepest incurvature between the vermilion border of the lower lip and the soft tissue chin, see Figure 2.

Average measurement for inferior sulcus to H-line is 5mm.

Figure 2 - Nasal prominence, soft tissue subnasale and lower lip to H-line and soft tissue chin thickness (Jacobson 1995)



6. **<u>Lower lip to H line</u>**

This measurement is made from the H-line to the most prominent outline of the lower lip, see Figure 2.

When the measurement has a negative value, it means the lower lip is behind the H-line and when it is positive it indicates that the lower lip is in front of the H-line.

The lower lip's ideal position with reference to the H-line is 0 mm to 0.5 mm anterior. Variations do exist and measurements of -1mm to 2 mm is still regarded as a good position.

When the lower lip position exceeds less than -1 mm with the other profile measurements being good, it normally indicates lower incisors that are positioned too far lingually.

On the other hand, when the lower lip exceeds more than 2mm beyond the H-line, the teeth are usually protrusive, and an increased overjet and overbite is normally present.

7. Soft tissue chin thickness

This represents the horizontal measurement of the distance between the hard-tissue and soft-tissue facial planes at the level of suprapogonion, as describes by Ricketts', see Figure 2.

The average distance is 10 to 12 mm.

Normally the two vertical lines (hard and soft tissue facial planes) diverge only slightly from the Nasion area down to the chin.

It is important to recognise large measurements. The implication of large measurements is that the lower and upper incisors should be left in a more anterior position, so that the much-needed lip support is not reduced.

8. Skeletal profile convexity

Measured from the facial plane (Nasion-Pogonion) to point A, see Figure 3.

This measurement is not a soft tissue measurement, but convexity is a good parameter to assess lip positions to facial skeletal convexity.

Harmonious lip positions again have a bearing on the dental relationships necessary to produce harmony of the human facial features. The measurement tends to range from -2 to 2mm

9. H angle

The H angle is an angular measurement formed by the intersection of the H-line and the soft-tissue facial plane/soft tissue Nasion-Pogonion line, see Figure 3.

The ideal measurement for the H-angle is 10 degrees when the convexity measurement is 0 mm. However, measurements of 7 to 15 degrees can all fall in good range as dictated by the convexity present, see Figure 4.

In ideal situations the convexity will increase together with the H angle to ensure a harmonious soft tissue drape in varying degrees of profile convexity.

Therefore, convex, straight and concave profiles can have soft tissues that are in balance and harmony, provided that the H-angle and convexity measurements approximate each other.

In cases where the H-angle and convexity do not approximate the measurements in the table, see Figure 4, it can be assumed that facial imbalance may be evident.

Figure 3 - Skeletal profile convexity, H-angle (Jacobson 1995)

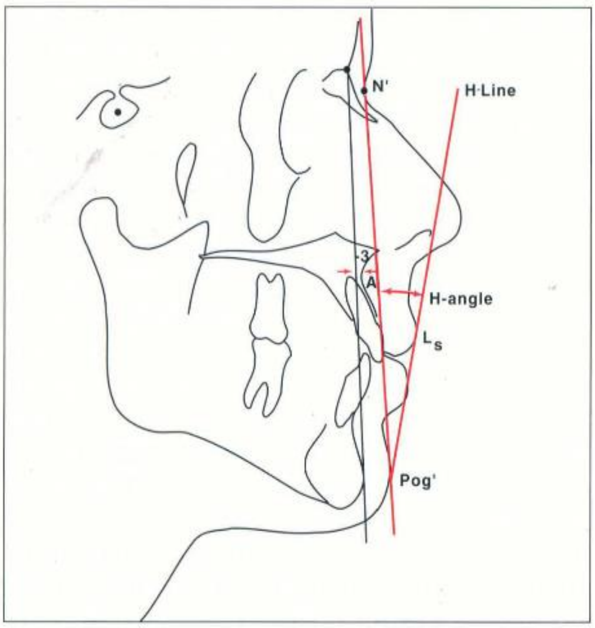


Figure 4 - H-Line angle measurements (Jacobson 1995)

Convexity Point A to Na–Pog (mm)	H-line angle (degrees)	
–5	5	
–4	6	
–3	7	
–2	8	
–1	9	
0	10	
1	11	Best Range
2	12	
3	13	
4	14	
5	15	
6	16	
7	17	
8	18	
9	19	
10	20	

*There is no single H-line angle that can be used as an ideal for all facial types, since the angle increases proportionately as the skeletal convexity varies from case to case.

10. Upper lip thickness at A-Point

This is a horizontal measurement from a point 3mm below point A, near the base of the alveolar process, to the outer border of the upper lip, see Figure 5.

The area of measurement is significant because at the exact point, the nasal structures do not have an influence on the drape of the lip.

It is a useful measurement, especially when compared to the lip thickness overlying the incisor crowns, because of its ability to determine the amount of lip incompetency or strain that exist when patients close their lips over protrusive teeth.

Average measurement is 15mm.

11. <u>Upper lip strain measurement – Upper lip thickness at vermilion border.</u>

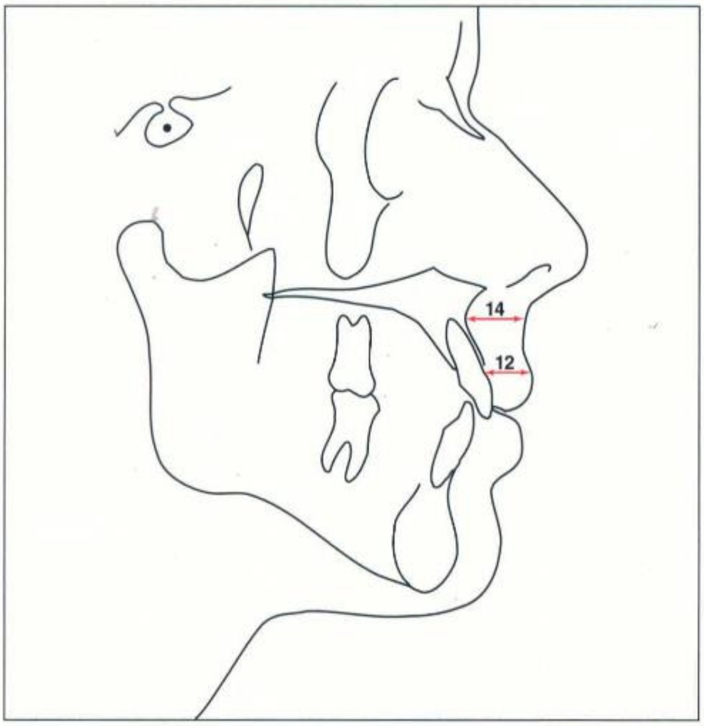
This measurement is made by measuring the distance from the labial surface of the maxillary central incisor to the vermilion border of the upper lip, see Figure 5.

The usual measurement is 13 to 14 mm. This measurement should ideally fall within 1mm of the basic upper lip thickness (measured 3mm below A point).

If the measurement is less, it indicates thinning of the upper lip as it is stretched over protrusive teeth, with resultant lip strain. The difference between the two measurements indicates the strain factor in millimetres.

An excess of vertical height can also lead to more than 1mm of taper due to stretching of the upper lip. In cases where this measurement is larger than the basic upper lip thickness, it usually indicates a lack of vertical growth of the patient's lower face, as well as a deep overbite.

Figure 5 - Upper lip thickness – upper lip strain (Jacobson 1995)



According to Holdaway (1983) the ideal facial similarities associated with beauty can be summarised as follows:

- A well-positioned soft-tissue chin in the facial profile
- Lower lip on the H line or at least within 1 mm of it.
- The form and sulcus depth of the lower lip in harmony with those of the upper lip.
- Absence of any severe skeletal profile convexity measurements.
- H angle that is within 1 or 2 degrees of average, for the convexity measurement of the patient (See Figure 3).
- Upper lip with a definite curl, measuring in the range of 4 to 6 mm in depth of the superior sulcus to the H line, as well as 2.5 to 4 mm to a line drawn perpendicular from the Frankfort horizontal.
- Nose prominence and soft tissue chin thickness without any unusual large or small measurements.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3. Introduction

The previous chapter explained in depth the history behind extractions in orthodontic treatment, with special reference to premolar extractions. The decision to extract second premolars was explored and explained. The chapter dealt with possible soft tissue profile changes that occur when second premolars are extracted for orthodontic treatment. The chapter ended with describing a self-ligating bracket system, the Damon system, as well as the use of the Holdaway cephalometric analysis that analyses soft tissues of patients using cephalometric radiographs. This chapter deals with the research design and methodology that was used to conduct this study.

3.1. Aim

The aim of this study was to compare the soft tissue profile changes of extraction (upper and lower second premolars) and non-extraction cases before and after orthodontic treatment.

3.2. Objectives:

- To make use of cephalograms and the Holdaway cephalometric analysis to measure the soft tissue profile of subjects that were treated with second premolar extractions, and without extractions, **before** treatment commenced.
- Using the same method, measure the soft tissue profile of the subjects, **after** treatment has finished.
- Compare the extraction and non-extraction subjects' soft tissue profile changes between the different groups.
- Determine the amount and extent of soft tissue changes that can be expected when second premolars are removed, compared to non-extraction, for orthodontic treatment, when using the Damon self-ligating system.

3.3. Research Hypothesis

There are no significant soft tissue changes when comparing non-extraction and second premolar extraction cases treated with the Damon system.

3.4. Study Design

This is a retrospective study evaluating changes that occurred from the start to the completion of treatment of orthodontic patients included in the study.
Lateral cephalograms were obtained before treatment (T1) and after treatment commenced (T2). All radiographs were taken with the same cephalostat (Kodak 8000C – Digital Panoramic and Cephalometric System – See figure 6).
Images were taken with patients/subjects in a standing position, the Frankfort plane parallel to the horizontal, teeth in centric occlusion and the lips relaxed.
All radiographs were traced and measured by the same investigator on Dolphin Imaging 11.5 Software (Dolphin imaging and Management Solutions, Chatsworth, California, USA).
Cephalometric values were compared before treatment (T1) and after treatment (T2) by making use of the Holdaway analysis that consists of 11 different variables in total, of which 9 are linear and 2 angular.

3.5. Sampling technique

All the patients were selected from the practice of one specialist orthodontist to ensure that the same technique and orthodontic system was used for all patients.

Samples of the two different groups were chosen after a propensity score matching was performed. Propensity score matching was introduced in 1983 by Rosenbaum and Rubin. This method pairs treatment and control samples with similar values on the propensity score, and possible other covariates, and completely discards unmatched samples (Rubin 2001). It is designed to compare two groups, but can also be applied in studies with more than two groups. The propensity score matching technique was used to ensure that the two groups are similar enough to be compared.

The propensity score matching was done using 3 variables, see Table 1. The steps used to conduct the propensity score matching is shown in Appendix 4.

Table 1 - Variables used for propensity score matching

	Variables	Range
1	Maxillary crowding	4 – 8 Millimeters
2	Mandibular crowding	4 – 8 Millimeters
3	Lower incisor inclination	85 – 110 Degrees

These variables were chosen because they represent patients that could have been subjected to either non-extraction or extraction treatments. The crowding was obtained by doing a space analysis on the digital orthodontic study models and the lower incisor inclination from the cephalometric analysis of each patient.

3.6. Sample Size

The initial group of patients that were treated by either non-extraction or extraction of the upper and lower second premolars, using the Damon system, were calculated as 255 cases.

After the propensity score matching was performed, see Appendix 4, 60 cases were selected, of which 25 were second premolar extraction cases and 35 were non-extraction cases.

3.7. Inclusion Criteria

- Cases with moderate to severe crowding (4-8 mm in both maxilla and mandible)
- Cases with a lower incisor inclination of 85 – 110 degrees.
- Group 1 - Treated cases where second premolars have been removed as part of a consented treatment plan.
- Group 2 - Treated cases where no teeth have been removed that match with the extraction cases, based on the propensity score matching.

- Patients without congenitally missing teeth or previous dental extractions.
- Absence of any orthognathic surgery or functional appliances prior to the treatment.
- Extraction spaces completely closed at the end of treatment.
- Only cases with high quality records (Cephalometric radiographs) were included in the study.
- All cephalograms were digitized and analyzed by one person (author of thesis – Dr JC Julyan)
- Only cases where the patients or their parents (depending on age) signed consent were included.
- Only subjects that have been treated by the same orthodontist and using the Damon technique was included.

3.8. Exclusion Criteria

- Cases where the parent did not sign consent for records to be used for research purposes.
- Cases with poor quality cephalometric radiographs or where radiographs, either before or after treatment were not present.
- Cases that were treated with any other orthodontic system besides the Damon system.
- Cases with asymmetrical premolar extractions.
- Any uncompleted cases or cases where patients stopped treatment before the final result was achieved.

3.9. Ethics approval and consent

This research protocol was presented to the Biomedical Research Ethics Committee at the University of the Western Cape, for registration as an approved research project. Approval to conduct the study was given on 24 November 2017 (See Appendix 3).

All the subjects or parents of the involved subjects in the study, signed the consent form for their records to be used for research (See Appendix 1). All information obtained during the course of this research remains strictly confidential and data that may be reported in law or scientific journals will not include any information which identifies the participants in this study. Data / information will be published anonymously. No information will be disclosed to any third party without written permission.

<u>The records that were used of the patients included:</u>

- Digital orthodontic study models to perform the propensity score matching.
- 2 Cephalometric radiographs

All the records are routinely done for all patients and no additional radiographs were taken of any of the patients involved in the study.

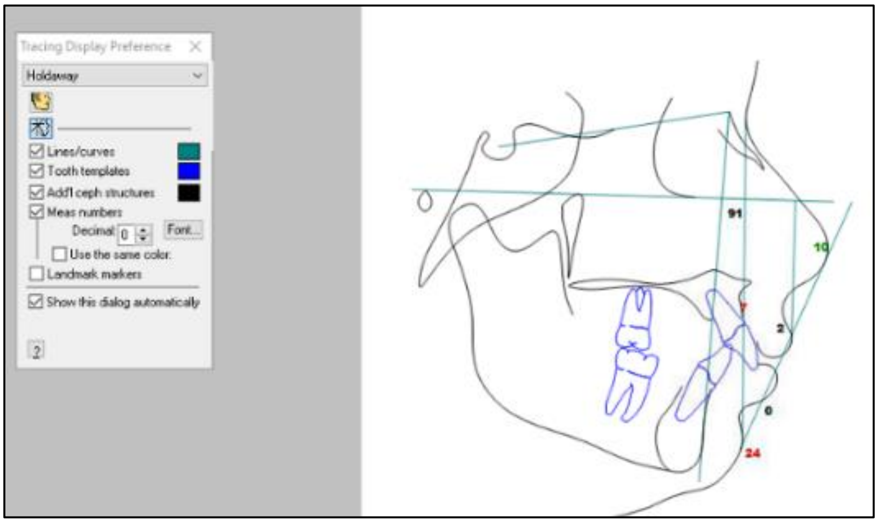
3.10. Research instruments

- Cephalostat that took the Cephalometric radiographs of the subjects involved (Kodak 8000C – Digital Panoramic and Cephalometric System), see Figure 6.

- Dolphin orthodontic software was used to do the Holdaway cephalometric analysis, both before and after treatment, see Figure 7.

Figure 6 - Cephalostat (Kodak 8000C)

Figure 7 - Dolphin orthodontic software



3.11. Data Collection

All the data was obtained from one specialist orthodontist. All the subjects were treated by the same specialist orthodontist and records of the participating subjects included:

- Cephalometric radiographs (Before and after treatment).
- Orthodontic study models to measure the crowding of the patients for the case selection.

The records were collected from the database of the orthodontist. Cases that met the inclusion criteria were selected and their records used to conduct the research.

3.12. Data Analysis

Dolphin orthodontic software was used to digitally conduct the cephalometric analysis. The Holdaway cephalometric analysis was used to measure the values both before and after the treatment. These values are displayed in Table 2.

Table 2 - Holdaway cephalometric analysis measurements and norms

Measurements	Norm	Acceptable range
Convexity (A-NPo) [mm]	-2 mm – 2 mm	-2 mm – 2 mm
Lower Lip to H-Line [mm]	0 mm	-1 – 2 mm
Soft Tissue Facial Angle (FH-N'Pg') [°]	91 Degrees	84 – 98 Degrees
Superior Sulcus Depth [mm]	3 mm	1 – 4 mm
Soft-tissue subnasale to H-Line [mm]	5 mm	3 – 7 mm
U-Lip Thickness @ A Point [mm]	15 mm	14 – 16 mm
U-Lip Thickness @ Ver Border [mm]	13 - 14 mm	13 - 14 mm
H-Angle (Pg'UL-Pg'Na') [°]	10 Degrees	7 - 15 Degrees
Inferior Sulcus to H-Line [mm]	5 mm	4 - 6 mm
Chin Thickness (Pg-Pg) [mm]	10-12 mm	10 – 12 mm
Nasal Prominence [mm]	14,8 mm	14 – 24 mm

Data collection sheets were made on Microsoft Excel. All the cephalometric radiographs were measured, and data was entered into the spreadsheets the day after all measurements were completed.

To minimise any unwanted errors, the entries were re-checked more than once after it was entered into the spreadsheet.

The data was sent to Professor Carl Lombard, at the South African Medical Research Council, for statistical analysis.

The Two One-Sided Significance Tests (TOST) for establishing equivalence were used to analyse the data.

First the difference between post- and pre-treatment values were calculated for each patient. The 90% confidence interval was then estimated for the difference between differences of the two groups using a linear regression model of the differences (pre- and post-treatment) on the group as a fixed effect and the baseline value as a covariate.

The estimated 90% confidence interval was then compared against the pre-specified margin of equivalence using a symmetric +/- interval of the margin.

Finally, the interference for each variable was concluded.

3.13. Possible limitations and gaps in the data

As cited by Hillesund *et al*. (1978), Mamandras (1984) and Talass *et al.* (1987), in the article of Wholley and Woods (2003), any retrospective lateral cephalometric study possesses the potential for patients to have voluntary or involuntary muscle activity during the taking of the cephalometric radiograph photos. This may of course affect the accuracy of the measurements made from these radiographs. However, the relative inability to properly quantify such measurement errors is unfortunately a shortcoming of all studies done by making use of retrospective cephalometric radiographs.

CHAPTER 4

RESULTS

4. Introduction

The previous chapter explained the methodology that was used to collect the data, as well as the instruments used and their application. This chapter presents the actual sample characteristics and the results of the Holdaway analysis for all the cephalometric radiographs used in the study. In chapter 5 the results will be discussed and compared with the literature.

4.1 Sample size

The initial group of patients that were treated by either non-extraction or extraction of the upper and lower second premolars, using the Damon system, were calculated as 255 cases.
After the propensity score matching was performed, 60 cases were identified that met the necessary criteria based on the three variables used (See Appendix 4).

4.1.1 Propensity Score Matching

After the propensity score matching was performed, 60 cases were identified, based on the initial amount of crowding in the maxilla and mandible, as well as the lower incisor inclination.
The 60 cases were made up of 35 non-extraction cases and 25 cases where the upper and lower second premolars were extracted for orthodontic treatment.
The descriptive statistics of the maxillary crowding, mandibular crowding and lower incisor inclination of the 60 selected cases are given in Table 3.

Table 3- Descriptive statistics of crowding and lower incisor inclination of the 60 selected cases.

	Average	Highest	Lowest
Maxillary crowding	5.45 mm	8.0 mm	4.1 mm
Mandibular crowding	5.62 mm	7.9 mm	4.0 mm
Lower incisor inclination	95.94°	109.6°	85.5°

4.2 Demographic information of the sample

4.2.1 Age

The mean age was 17 Years and 4 Months (ranging from 10 years and 8 months to 54 years and 9 Months of age). The descriptive statistics of age for both groups are given in Table 4.

Table 4 – Descriptive Statistics of Age (in Years)

Age (years)	Total (n)		Total (%)
	Extraction	Non-extraction	
10 – 17.9	21	27	80.0
17.9 - 25.8	2	2	6.7
25.8 – 33.7	1	3	6.7
33.7 – 41.6	0	1	1.7
41.6 – 49.5	1	1	3.3
49.5 – 57.4	0	1	1.7

4.2.2 Gender

Of the 60 patients, 24 (40 %) were male and 36 patients (60 %), the majority of the sample, were female. The descriptive statistics of the gender distribution is given in Table 5.

Table 5 – Descriptive Statistics of the Gender distribution of the sample

Gender	Total (n)	Total (%)
Male	24	40
Female	36	60
Total	**60**	**100**

4.3 Holdaway Cephalometric analysis

Below are the results of the Holdaway soft tissue cephalometric analysis for all the cases involved in the study. It includes the values of the extraction and non-extraction groups both before and after treatment. The changes that occurred in both the extraction and non-extraction groups, are also given.

4.3.1 Descriptive statistics of pre-treatment values

The values obtained from the Holdaway cephalometric analysis for both groups before treatment commenced is shown in Table 6 below. These values were used as the baseline.

Table 6 - Pre-treatment values

Pre - Treatment						
Measurement	Extraction group			Non - Extraction group		
	N	Mean	SD	N	Mean	SD
Convexity (mm)	25	3.752	2.578132	35	2.185714	2.102679
Lower Lip to H-line (mm)	25	1.908	1.212408	35	0.3428571	1.528414
Soft Tissue Facial Angle (Degrees)	25	92.088	4.181041	35	92.70571	4.55082
Superior Sulcus Depth (mm)	25	2.176	1.639177	35	2.32	1.363344
Subnasale to H-line (mm)	25	5.74	2.80119	35	3.1	3.207803
Upper Lip Thickness at A-point (mm)	25	13.972	3.124969	35	14.40857	2.330788
Upper Lip Thickness at Vermilion Border (mm)	25	10.44	2.709859	35	11.60571	2.507159
H- Angle (Degrees)	25	16.276	4.030331	35	12.54571	4.811099
Inferior Sulcus to H-line (mm)	25	3.812	1.815975	35	4.302857	1.625619
Chin Thickness (mm)	25	12.028	3.22342	35	12.02	2.360309
Nasal Prominence (mm)	25	10.516	3.420731	35	12.48857	4.831744

Since this was a non-randomised study the baseline values were compared for balance between the two groups using a 2-sample t-test.

- Four parameters showed a significant difference at baseline between the groups despite the prior matching.

- Therefore, an adjustment was made for the baseline measurement in the analysis.

4.3.2 Descriptive statistics of post-treatment values

Table 7 below represent the values obtained from the Holdaway cephalometric analysis for both the extraction and non-extraction groups at the end of treatment.

Table 7 - Post-treatment values

Post - Treatment						
Measurement	Extraction group			Non - Extraction group		
	N	Mean	SD	N	Mean	SD
Convexity (mm)	25	2.812	2.327252	35	1.185714	2.691287
Lower Lip to H-line (mm)	25	1.256	1.162999	35	1.26	1.370745
Soft Tissue Facial Angle (Degrees)	25	92.984	4.746286	35	93.60286	3.380436
Superior Sulcus Depth (mm)	25	2.52	1.788621	35	2.997143	1.479166
Subnasale to H-line (mm)	25	4.868	1.893788	35	4.185714	2.971249
Upper Lip Thickness at A-point (mm)	25	13.264	1.998308	35	14.94857	1.862379
Upper Lip Thickness at Vermilion Border (mm)	25	12.22	1.928082	35	11.64571	1.755385
H- Angle (Degrees)	25	14.656	3.131304	35	13.18857	3.334205
Inferior Sulcus to H-line (mm)	25	4.112	1.138464	35	4.348571	1.491815
Chin Thickness (mm)	25	11.792	1.948487	35	12.27143	1.806129
Nasal Prominence (mm)	25	11.9	4.058633	35	12.30286	4.090627

4.3.3 Descriptive statistics of changes

A difference of differences approach was used for the comparison of the groups.
Step 1: calculate difference between post and pre-treatment values.
Step 2: compare these changes between the groups adjusted for baseline
Table 8 below represent the values of the changes that occurred from the start to the end of treatment, for both the extraction and non-extraction groups.

Table 8 - Treatment changes

Difference (T2-T1)						
Measurement	Extraction Group			Non-Extraction Group		
	N	Mean	SD	N	Mean	SD
Convexity (mm)	25	-0.94	1.705872	35	1	2.154749
Lower Lip to H-line (mm)	25	-0.652	1.384172	35	0.9171429	1.113945
Soft Tissue Facial Angle (Degrees)	25	0.896	3.489804	35	0.8971429	3.831102
Superior Sulcus Depth (mm)	25	0.344	1.174053	35	0.6771429	1.244065
Subnasale to H-line (mm)	25	-0.872	2.028242	35	1.085714	2.123557
Upper Lip Thickness at A-point (mm)	25	-0.708	3.619613	35	0.54	2.292084
Upper Lip Thickness at Vermilion Border (mm)	25	1.78	2.435159	35	0.04	2.795395
H- Angle (Degrees)	25	-1.62	1.930242	35	0.6428571	3.162583
Inferior Sulcus to H-line (mm)	25	0.3	1.397915	35	0.0457143	1.2363
Chin Thickness (mm)	25	-0.236	2.674553	35	0.2514286	2.266297
Nasal Prominence (mm)	25	1.384	2.668907	35	-0.1857143	2.65265

The Figures 8 to 18 below are a graphical representation of the changes in values for both the extraction and non-extraction groups, before and after orthodontic treatment.

Figure 8 - Graph illustrating changes in nasal prominence for both groups

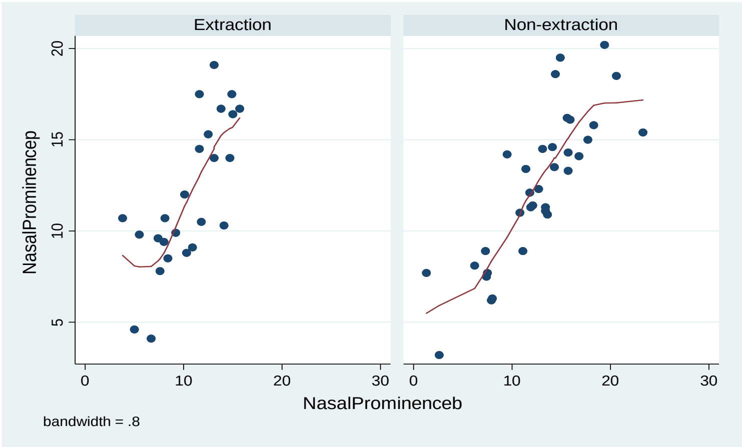


Figure 9 - Graph illustrating changes in superior sulcus depth for both groups

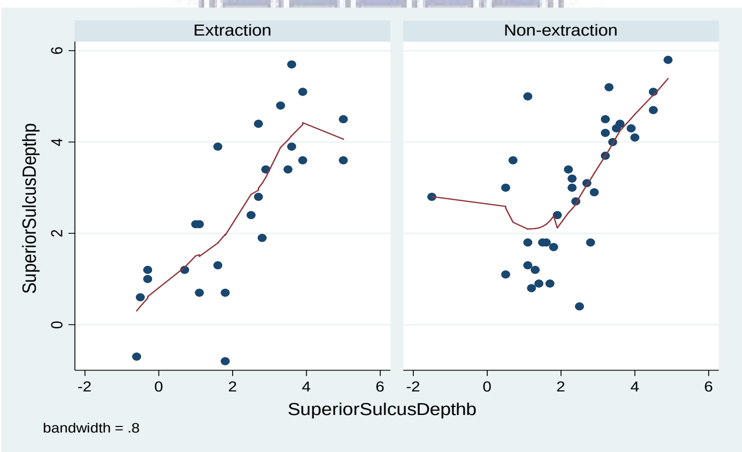


Figure 10 - Graph illustrating changes in Convexity for both groups

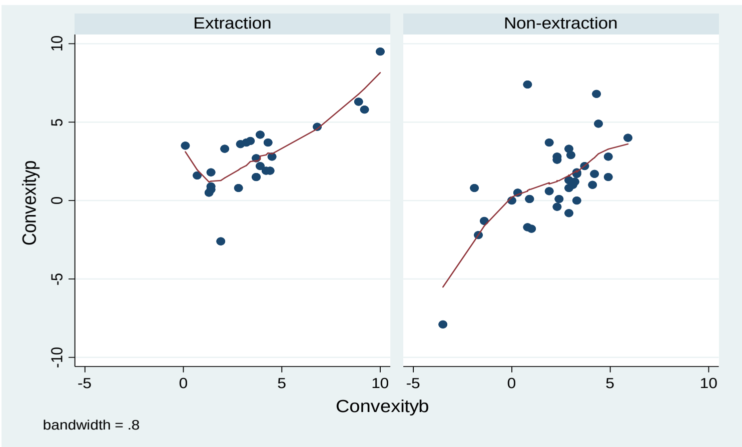


Figure 11 - Graph illustrating changes in lower lip to H-line for both groups

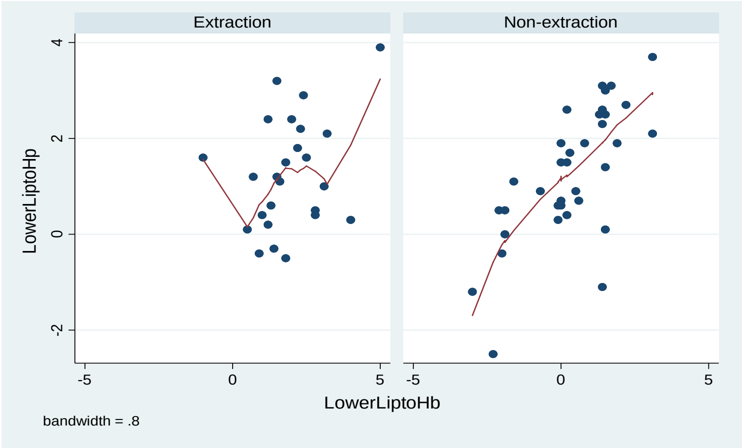


Figure 12 - Graph illustrating changes in H-angle for both groups

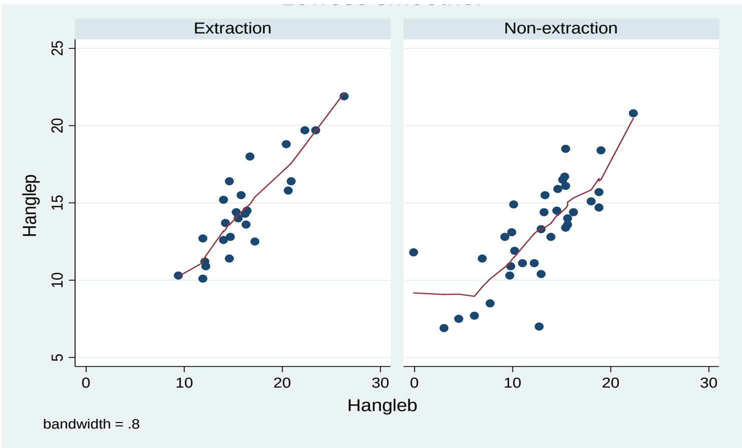


Figure 13 - Graph illustrating changes in upper lip thickness for both groups

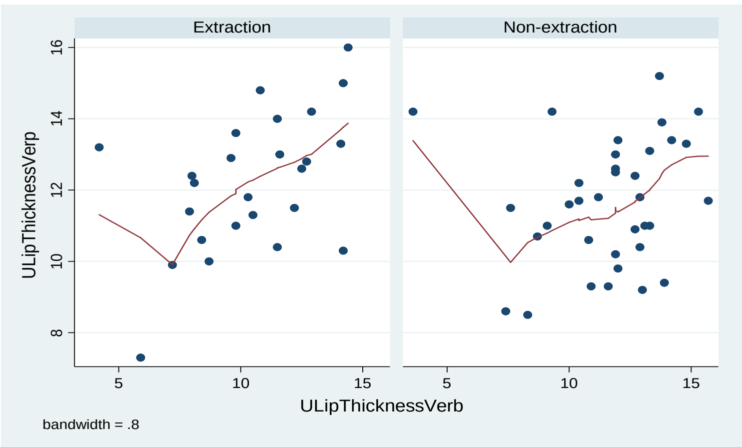


Figure 14 - Graph illustrating changes in chin thickness for both groups

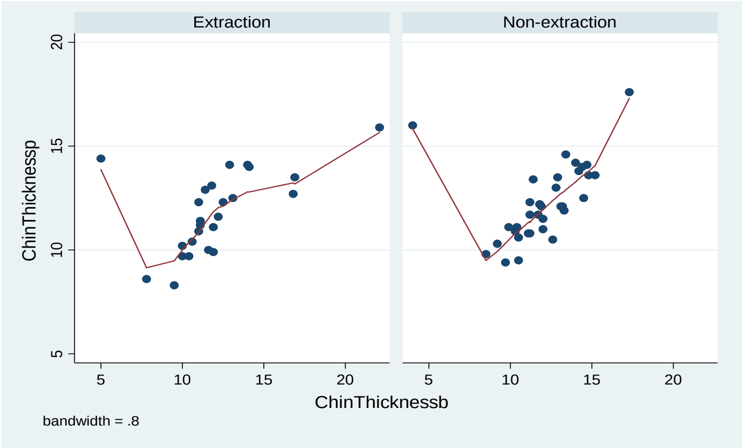


Figure 15 - Graph illustrating changes in facial angle for both groups

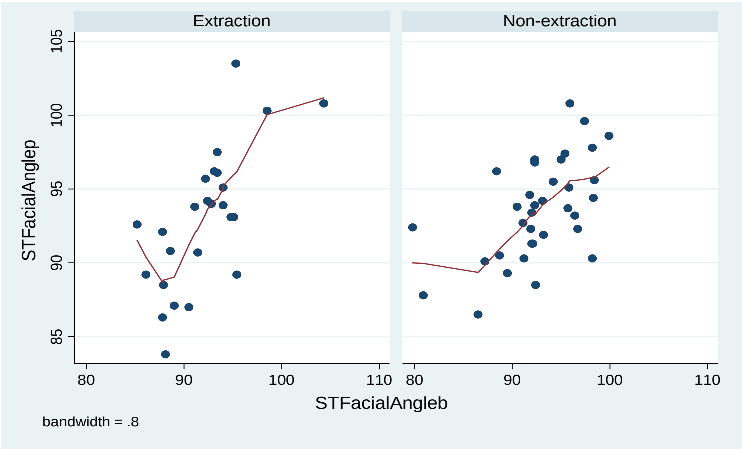


Figure 16 - Graph illustrating changes in upper lip thickness for both groups

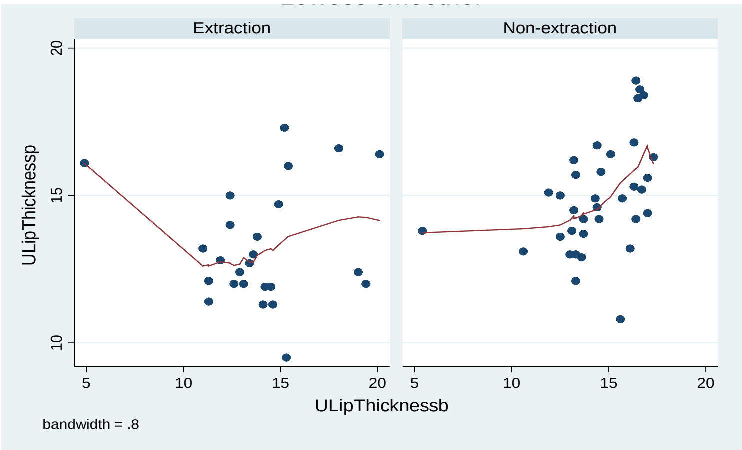


Figure 17 - Graph illustrating changes in inferior sulcus to H-line for both groups

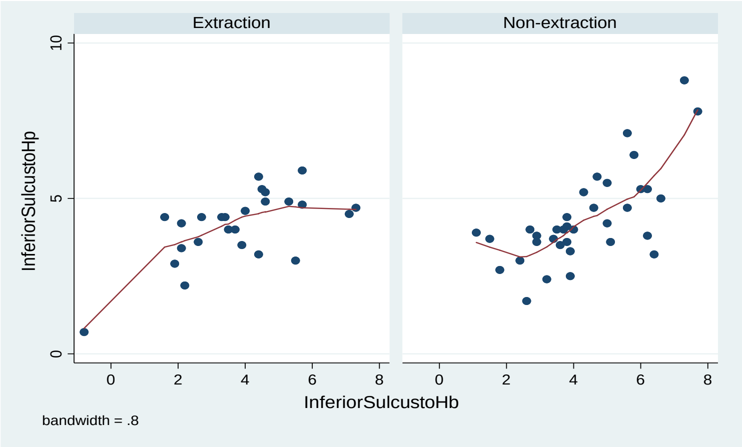
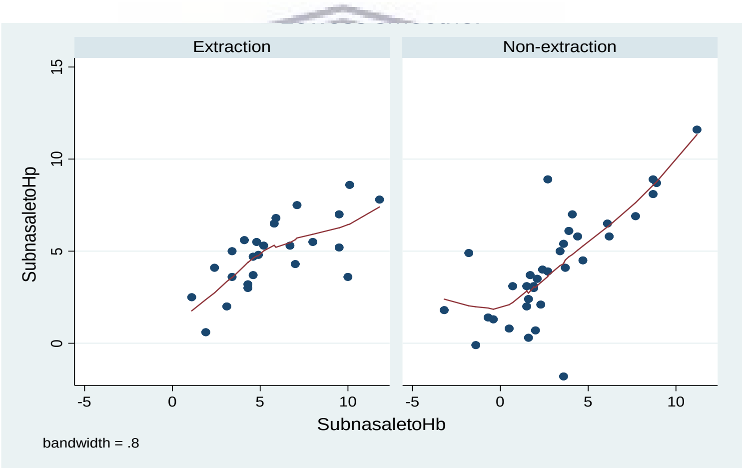


Figure 18 - Graph illustrating changes in subnasale to H-line for both groups



See Appendix 5 for a box plot graphical comparison of the extraction and non-extraction groups' cephalometric values before treatment, and of the changes that occurred during treatment for both groups.

Inference testing was done for the difference between groups using a linear regression model of the difference on group and baseline value. The difference on outcome was estimated with 95% confidence intervals

Only two variables showed a difference between the groups:

- Lower lip to H-line.
- Upper lip thickness @ A point.

The primary hypothesis was to prove that extraction of upper and lower second premolars will not make a difference on the soft tissue profile of patients.
The hypothesis is therefore one that aims to prove equivalence between extraction and non-extraction groups, when the Damon system is used.

The Two One-Sided Significance Tests (TOST) for establishing equivalence were used to analyze the data, see Table 9 and Figure 19.
TOST is an alternative to the well-known two-sample *t*-test. The TOST is designed to specifically test for bioequivalence. TOST commences with a null hypothesis that two mean values are not equivalent. The test then attempts to prove that the two mean values are equivalent within a pre-set limit.
This is opposite to the two-sample t-test. In comparison to the two-sample *t*-test, the TOST penalizes poor precision and it requires the analyst to prove that the given data sets, are equivalent (Limentani *et al*. 2005).

In this study the difference between post- and pre-treatment values were calculated for each patient. The 90% confidence interval was then estimated for the difference between differences of the two groups using a linear regression model of the differences (pre-post treatment) on the group as a fixed effect and the baseline value as a covariate.

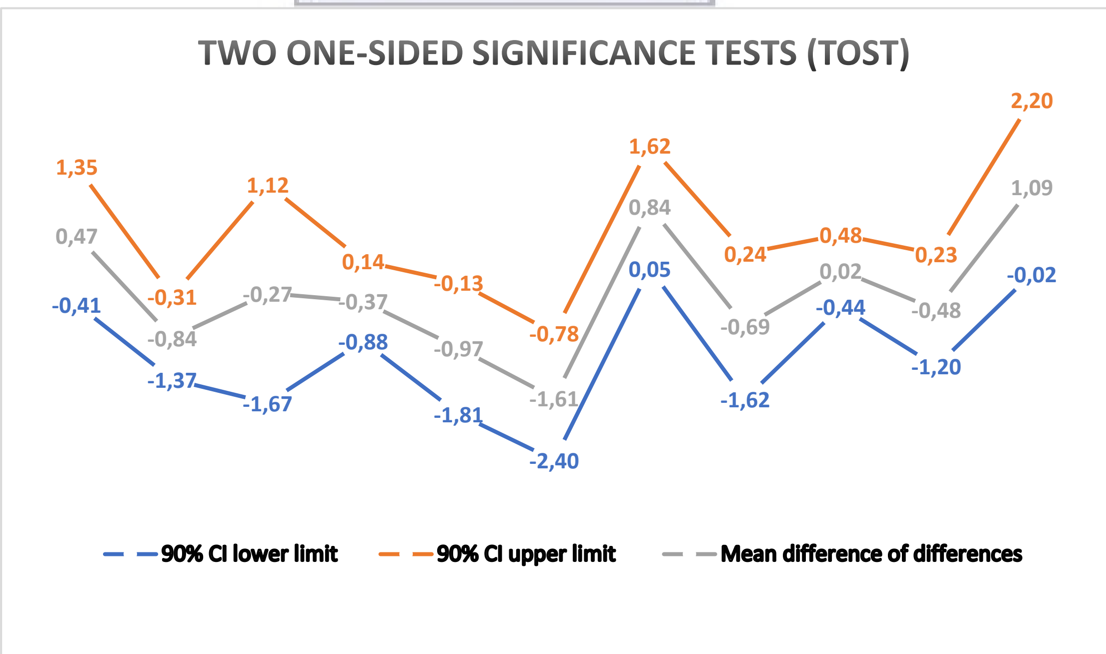
The estimated 90% confidence interval was then compared against the pre-specified margin of equivalence using a symmetric +/- interval of the margin.

Finally, the interference for each variable was concluded.

Table 9 - Two one-sided significance test

Two One-Sided Significance Tests (TOST)					
Variable	Margin for equivalence	90% CI lower limit	90% CI upper limit	Conclusion	Mean difference of differences
Convexity (mm)	2	-0.41	1.35	Equivalent	0.47
Lower Lip to H-Line (mm)	2	-1.37	-0.31	Not equal but equivalent	-0.84
S.T. Facial Angle (°)	7	-1.67	1.12	Equivalent	-0.27
Superior Sulcus Depth (mm)	1	-0.88	0.14	Equivalent	-0.37
Subnasale to H-Line (mm)	2	-1.81	-0.13	Not equal but equivalent	-0.97
U-Lip Thickness @ A Point (mm)	3	-2.40	-0.78	Not equal but equivalent	-1.61
U-Lip Thickness @ Ver Border (mm)	3	0.05	1.62	Equivalent	0.84
H-Angle (°)	4	-1.62	0.24	Equivalent	-0.69
Inferior Sulcus to H-Line (mm)	2	-0.44	0.48	Equivalent	0.02
Chin Thickness (mm)	3.5	-1.20	0.23	Equivalent	-0.48
Nasal Prominence (mm)	3	-0.02	2.20	Equivalent	1.09

Figure 19 - Graphical representation of the TOST conducted



CHAPTER 5

DISCUSSION

5. Introduction

The previous chapter presented the results of the Holdaway analysis for both the extraction and the non-extraction groups, both before and after treatment. It also presented the results of the changes that occurred in both groups before and after treatment. This chapter will discuss the results and findings and compare it to reviewed literature.

5.1 Background

A study comparing soft tissue profile changes in patients treated without extractions, and with upper and lower second premolar extractions, using the Damon system, has not been found in any orthodontic literature.

Nance (1941) and Dewel (1955), both suggested the extraction of upper and lower second premolars in cases that present with mild to moderate crowding and acceptable soft tissue profiles before treatment. They both motivated that this extraction pattern should have the least effect on the soft tissue facial profile of the patients.

The study aimed to compare the soft tissue profile changes of extraction (upper and lower second premolars) and non-extraction cases before and after orthodontic treatment, when using the Damon system. The hypothesis was to prove equivalence between the results of the two groups involved in the study.

The study made use of 60 patients that were treated either with four second premolar extractions or without any extractions.

All the patients were treated by the same orthodontist and all were treated with the Damon orthodontic system.

The Holdaway soft tissue cephalometric analysis was used to conduct the study by making use of lateral cephalograms of all the patients before, and after treatment.

The Holdaway analysis is made up of 11 measurements: 2 angular and 9 linear measurements.

5.2 Holdaway Analysis

The results of the 11 measurements for both groups involved in the study are displayed below. The mean change for each measurement was calculated by subtracting the mean value before treatment from the mean value after treatment.

1. **Skeletal profile convexity**:

   Skeletal convexity is a good parameter to assess lip positions to facial skeletal convexity. The measurement normally ranges from -2 mm to 2 mm.

   The **extraction** group had a mean skeletal profile convexity measurement of 3.752 mm before treatment commenced, and it changed to 2.812 mm at the completion of treatment.

   There was therefore -0.94 mm mean change.

   The **non-extraction** group had a mean skeletal profile convexity measurement of 2.185 mm before treatment commenced, and it changed to 1.185 mm at the completion of treatment.

   There was therefore -1.0 mm mean change.

   For both groups the skeletal profile convexity decreased during treatment. The extraction group had a mean change of -0.94 and the non-extraction group a mean change of -1.0 mm. Both groups ended with a measurement that fell within or very close to the normal range for skeletal profile convexity as set out by Holdaway (1983).

2. **Lower lip to H-line:**

   The ideal position of the lower lip is 0 – 0.5 mm behind the H-line. The position can vary and measurements of -1mm to 2 mm are still regarded as a good position.

   The **extraction** group had a mean lower lip to H-line measurement of 1.908 mm before treatment commenced, and it changed to 1.256 mm at the completion of treatment.

There was therefore -0.65 mm mean change.

The **non-extraction** group had a mean lower lip to H-line measurement of 0.342 mm before treatment commenced, and it changed to 1.260 mm at the completion of treatment.

There was therefore 0.91 mm mean change.

The lower lip to H-line measurement decreased in the extraction group and increased in the non-extraction group. Both groups ended with measurements within the acceptable range of -1 mm to 2 mm for the lower lip to H-line measurement.

3. **Superior sulcus depth**:

The ideal for this measurement is 3mm, but a range of 1-4 mm is considered to be acceptable. A measurement of 3mm indicates average thickness lips. In patients with thin lips the measurement decreases, and it increases in patients with thick lips.

Holdaway (1983) suggests that the superior sulcus depth measurement not decrease to less than 1.5 mm during orthodontic treatment.

The **extraction** group had a mean superior sulcus depth measurement of 2.176 mm before treatment commenced, and it changed to 2.520 mm at the completion of treatment.

There was therefore 0.34 mm mean change.

The **non-extraction** group had a mean superior sulcus depth measurement of 2.320 mm before treatment commenced, and it changed to 2.997 mm at the completion of treatment.

There was therefore 0.67 mm mean change.

The superior sulcus depth measurement increased in both the extraction group and the non-extraction group. The extraction group had a mean change of 0.34 and the non-extraction group a mean change of 0.67 mm. Both the extraction and non-extraction groups ended with measurements within the acceptable range for the superior sulcus depth measurement.

The increase in superior sulcus depth differs from the results of the study by Allgayer *et al*. (2011), who found the upper lip sulcus depth to reduce after treatment with premolar extractions.

4. **Soft tissue subnasale to H-Line:**

The ideal for this measurement is 5mm, but a range of 3-7 mm is considered to be acceptable. Patients with short and thin lips can have an adequate measurement of 3mm and longer and thicker lips with measurements of 7mm are still considered acceptable.

The **extraction** group had a mean soft tissue subnasale to H-line measurement of 5.740 mm before treatment commenced, and it changed to 4.868 mm at the completion of treatment.
There was therefore -0.87 mm mean change.
The **non-extraction** group had a mean soft tissue subnasale to H-line measurement of 3.100 mm before treatment commenced, and it changed to 4.185 mm at the completion of treatment.
There was therefore 1.08 mm mean change.

The soft tissue subnasale to H-line measurement decreased in the extraction group and increased in the non-extraction group. The extraction group had a mean change of -0.87 mm and the non-extraction group a mean change of 1.08 mm.

Both the extraction and non-extraction groups ended with measurements within the acceptable range for the superior sulcus depth measurement.

5. **Upper lip thickness at A-Point:**

The average measurement for upper lip thickness at A-point is 15mm.

The **extraction** group had a mean upper lip thickness at A-Point measurement of 13.972 mm before treatment commenced, and it changed to 13.264 mm at the completion of treatment.
There was therefore -0.70 mm mean change.

The **non-extraction** group had a mean upper lip thickness at A-Point measurement of 14.408 mm before treatment commenced, and it changed to 14.948 mm at the completion of treatment.
There was therefore 0.54 mm mean change.

The upper lip thickness at A-point measurement decreased in the extraction group and increased in the non-extraction group. The extraction group had a mean change of -0.70 mm and the non-extraction group a mean change of 0.54 mm. Both the extraction and non-extraction groups ended with measurements within the acceptable range for the superior sulcus depth measurement.

6. **Upper lip thickness at vermillion border (upper lip strain):**
The ideal measurement for upper lip strain is 13 to 14 mm and this measurement should ideally fall within 1mm of the basic upper lip thickness at the A-point.

The **extraction** group had a mean upper lip thickness at vermillion border measurement of 10.440 mm before treatment commenced, and it changed to 12.220 mm at the completion of treatment.
There was therefore 1.78 mm mean change.
The **non-extraction** group had a mean upper lip thickness at vermillion border measurement of 11.605 mm before treatment commenced, and it changed to 11.645 mm at the completion of treatment.
There was therefore 0.04 mm mean change.

The upper lip thickness at the vermilion border measurement increased in both the extraction group and the non-extraction group. The extraction group had a mean change of 1.78 mm and the non-extraction group a mean change of 0.04 mm. Both the extraction and non-extraction groups ended with measurements lower than the ideal range for the upper lip thickness at the vermilion border measurement.

7. **<u>Inferior sulcus to the H-Line (lower lip sulcus depth):</u>**

   The ideal measurement for inferior sulcus to H-line measurement is 5mm.

   The **<u>extraction</u>** group had a mean inferior sulcus to the H-line measurement of 3.812 mm before treatment commenced, and it changed to 4.112 mm at the completion of treatment.

   <u>There was therefore 0.30 mm mean change.</u>

   The **<u>non-extraction</u>** group had a mean inferior sulcus to the H-line measurement of 4.302 mm before treatment commenced, and it changed to 4.348 mm at the completion of treatment.

   <u>There was therefore 0.046 mm mean change.</u>

   The inferior sulcus to H-line measurement increased in both the extraction group and the non-extraction group. The extraction group had a mean change of 0.30 mm and the non-extraction group a mean change of 0.046 mm. Both the extraction and non-extraction groups ended with measurements within 1 mm of the ideal 5mm for the inferior sulcus to H-line measurement.

8. **<u>Soft tissue chin thickness:</u>**

   The average measurement is a distance of 10 to 12 mm for the chin thickness.

   The **<u>extraction</u>** group had a mean soft tissue chin thickness measurement of 12.028 mm before treatment commenced, and it changed to 11.792 mm at the completion of treatment.

   <u>There was therefore -0.23 mm mean change.</u>

   The **<u>non-extraction</u>** group had a mean soft tissue chin thickness measurement of 12.020 mm before treatment commenced, and it changed to 12.271 mm at the completion of treatment.

   <u>There was therefore 0.25 mm mean change.</u>

The soft tissue chin thickness measurement decreased in the extraction group and increased in the non-extraction group. The extraction group had a mean change of -0.23 mm and the non-extraction group a mean change of 0.25 mm. Both the extraction and non-extraction groups ended with measurements within 1 mm of the ideal range of 10 to 12 mm for the soft tissue chin thickness measurement.

9. **Nasal Prominence:**

A nasal prominence measurement below 14mm is considered small and higher than 24mm, large.

The **extraction** group had a mean nasal prominence measurement of 10.516 mm before treatment commenced, and it changed to 11.900 mm at the completion of treatment.
There was therefore 1.38 mm mean change.
The **non-extraction** group had a mean nasal prominence measurement of 12.488 mm before treatment commenced, and it changed to 12.302 mm at the completion of treatment.
There was therefore -0.18 mm mean change.

The nasal prominence measurement increased in the extraction group and decreased in the non-extraction group. The extraction group had a mean change of 1.38 mm and the non-extraction group a mean change of -0.18 mm.

Both the extraction and non-extraction groups ended with measurements within 1 mm below 14 mm, indicating the patients to fall in the small category for the nasal prominence measurement.

According to Hoffelder and Lima (2007), the nose has the potential to change up to the age of 18. The nose is expected to increase in size throughout life according to the study by Subtenly (1961).

10. **<u>Soft Tissue facial angle:</u>**

The ideal measurement for the soft tissue facial angle is 91 degrees, but a range of ± 7 degrees is regarded as being acceptable.

The **<u>extraction</u>** group had a mean soft tissue facial angle measurement of 92.088 degrees before treatment commenced, and it changed to 92.984 degrees at the completion of treatment.

<u>There was therefore 0.89 degree mean change.</u>

The **<u>non-extraction</u>** group had a mean soft tissue facial angle measurement of 92.705 degrees before treatment commenced, and it changed to 93.602 degrees at the completion of treatment.

<u>There was therefore 0.89 degree mean change.</u>

The soft tissue facial angle measurement increased in the extraction and non-extraction groups. The extraction group had a mean change of 0.89 mm and the non-extraction group a mean change of 0.89 mm. Both the extraction and non-extraction groups ended with measurements higher than the ideal 91 degrees, but still fell in the acceptable range for the soft tissue facial angle measurement.

11. **<u>H-Angle:</u>**

A measurement of 10 degrees is considered ideal when the convexity measurement is 0 mm. Measurements are dictated by the convexity measurement, and can still be acceptable when it falls in the range of 7 to 15 degrees.

The **<u>extraction</u>** group had a mean H- angle measurement of 16.276 degrees before treatment commenced, and it changed to 14.656 degrees at the completion of treatment.

<u>There was therefore -1.62 degrees mean change.</u>

The **non-extraction** group had a mean H- angle measurement of 12.545 degrees before treatment commenced, and it changed to 13.188 degrees at the completion of treatment.

There was therefore 0.64 degrees mean change.

The H-angle measurement decreased in the extraction group and increased in the non-extraction group. The extraction group had a mean change of -1.62 degrees and the non-extraction group a mean change of 0.64 degrees. Both the extraction and non-extraction groups ended with measurements higher than the ideal 10 degrees, but still fell in the acceptable range, as dictated by their final mean convexity measurements of 2.8 mm for the extraction group and 1.1 for the non-extraction group, after treatment.

Holdaway's (1983) ideal facial similarities associated with beauty include the following:

- **A well-positioned soft-tissue chin in the facial profile**

Both the extraction and non-extraction groups ended with measurements within the ideal range of 10 to 12 mm for the soft tissue chin thickness measurement.

- **Lower lip on the H line or at least within 1 mm of it.**

The extraction group ended with a mean measurement of 1.25 mm for the lower lip to the H- line and the non-extraction group with a mean of 1.26 mm.

- **The form and sulcus depth of the lower lip in harmony with those of the upper lip.**

The superior sulcus depth and inferior sulcus to H-line measurements increased in both the extraction group and the non-extraction group.

- **Absence of any severe skeletal profile convexity measurements.**

Both the extraction and non-extraction groups ended with measurements that fall within the normal range for skeletal profile convexity as set out by Holdaway (1983).

- **H angle that is within 1 or 2 degrees of average, for the convexity measurement of the patient.**

  Both the extraction and non-extraction groups ended with measurements higher than the ideal 10 degrees, but still fell in the acceptable range, as dictated by their final mean convexity measurements of 2.8 mm for the extraction group and 1.1 for the non-extraction group, after treatment.

- **Upper lip with a definite curl, measuring in the range of 4 to 6 mm in depth of the superior sulcus to the H line, as well as 2.5 to 4mm to a line drawn perpendicular from the Frankfort horizontal.**

  Both the extraction and non-extraction groups ended with measurements within the acceptable range for the superior sulcus depth measurement. Both the extraction and non-extraction groups ended with measurements lower than the ideal range for the upper lip thickness at the vermilion border measurement

- **Nose prominence and soft tissue chin thickness without any unusually large or small measurements.**

  Both the extraction and non-extraction groups ended with measurements within 1 mm below 14 mm, indicating that the patients fell in the small category for the nasal prominence measurement.

  Both the extraction and non-extraction groups ended with measurements within 1 mm of the ideal range of 10 to 12 mm for the soft tissue chin thickness measurement.

The findings of the study successfully proved the hypothesis that both non-extraction and second premolar extraction cases, treated with the Damon system, resulted in similar soft tissue profile changes.
The results of the study agree with that of Khan and Fida (2010), Young and Smith (1993) and Luppanapornlap and Johnston (1993), who all concluded that it is incorrect to blame any undesired facial aesthetics caused by orthodontic treatment, to the removal of premolars exclusively.

The study found that the soft tissue characteristics remain the same for both the extraction and non-extraction groups and that all the measurements at the completion of treatment fell within the acceptable ranges, as indicated by Holdaway (1983). In the study by Allgayer *et al*. (2011), the Holdaway analysis was used to determine the facial profile influence on the patients treated with premolar extractions.

Bishara *et al*. (1997), also made the statement that extraction and non-extraction treatment does not have a detrimental effect on the facial profile after treatment.

Findings from studies done by Rushing *et al*. (1995), as well as Johnson and Smith (1995), also found no significant difference when comparing the faces of extraction and premolar extraction patients after orthodontic treatment.

The results of this study agrees with that of Khan and Fida (2010) in that the facial profiles were very similar after treatment with different extraction protocols. Khan and Fida (2010), compared extraction and non-extraction cases and found that the effects caused by the two types of treatment on the facial soft tissues were similar. This was an indication that premolar extraction does not have an undesirable effect of facial aesthetics, provided that the mechanics of the treatment is well-controlled and the decision to extract is made on a sound basis.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn based on the results of this study described in chapter 4.

The results were equivalent when comparing the soft tissue profile changes of the extraction (upper and lower second premolar) and non-extraction cases. There were no statistical significant difference in soft tissue response between the two treatment groups, therefore proving the hypothesis of this study.

The Damon system, which is primarily a system that prides itself in non-extraction treatment, can be used in conjunction with upper and lower second premolar extractions, without compromising the soft tissue results of the patients.

From the results of this research it may be beneficial to do similar follow up studies with a bigger sample of patients (50 second premolar extraction and 50 non-extraction). The increased sample size will provide a more detailed study where individual cephalometric values can also be compared between different genders. It would also be ideal if the patients can be of the same age group to ensure that all the patients still have the same growth potential left and can be followed up as a group in future studies.

Another suggestion for future research would be to study the arch width differences and lower incisor inclination differences of a similar sample group. The non-extraction treatment with the Damon system often results in expanded arches and proclined incisors in order to align the teeth. Future studies using the same sample criteria of non-extraction and second premolar extraction groups can evaluate what the difference is in arch width and incisor inclination when comparing the two groups.

The results of the study can be used to educate patients about extractions and that there are not harmful effects when done after proper diagnosis and treatment planning. It is also important to inform patients of the possible dangers of always trying to treat malocclusions without extractions. Patients are subjected to social media and other marketing techniques where non-extraction treatment gets promoted. It is important for patients to understand that treatment differs for each individual case and cannot be generalized.

Dentists should also be informed of the treatment options available and the meticulous process of diagnosis and treatment planning necessary for each individual case. This will ensure that patients are not referred to orthodontists with the idea in mind that extractions will not be necessary and that non-extraction treatment is the best treatment in all cases.

Finally, it is important to note that the industry of orthodontic materials is marketing directly to the patients. Sometimes claims are made as to the capabilities of certain products without sufficient scientific evidence. It is the prerogative of clinical orthodontists to do proper clinical research and only read proper scientific validated articles, before applying the knowledge in making treatment decisions. This will be for the benefit of our profession and our patients.

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APPENDIX 1 :

Patient information sheet and informed consent clause

Department of Orthodontics

Faculty of Dentistry & WHO Oral Health Collaborating Centre

Private Bag X1, Tygerberg 7705
South Africa
Telephone: +27 21 937 3106/3030//3172

Private Bag X08, Mitchell's Plain 7785
South Africa
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Fax: +27 21 392 3250

PARTICIPANT INFORMATION LEAFLET

Title of project:
Soft tissue profile changes in patients treated with non-extraction versus second premolar extraction protocols - using the Damon system.

Introduction:
This information leaflet is to help you decide if you would like to participate in the above-mentioned study. Before you agree to take part in this study you should fully understand what is involved. If you have any questions, which are not fully explained in this leaflet, do not hesitate to ask the researcher.

What is the purpose of the study and how will it be conducted?
The aim of this study is to offer scientific data that dental extractions can be used in the Damon technique to establish a balanced dentition and acceptable profile. The study will evaluate the soft tissue changes that occurred in patients treated with second premolar extractions. These patients will be compared to patients treated with a non-extraction protocol.

Has the study received ethical approval?
This research protocol was submitted to the Biomedical Research Ethics Committee at the University of the Western Cape, and written approval has been granted by the Committee. The study has been structured in accordance with ethical considerations such as the protection of the identity of all participants.

What are my rights as a research participant in this study?
Your participation in this research is entirely voluntary and you can refuse to participate or stop at any time without stating any reason. The investigator retains the right to withdraw you from the study if considered to be in your best interest.

Insurance and financial arrangements:
Patients will not receive any compensation for participating in the study.

Researcher contact details:
Dr. JC Julyan

Tel: 021 975 7478 (work) / 074 136 3505 (cell)

Email: jcjulyan@gmail.com

Biomedical Research Ethics Committee, contact details

University of the Western Cape

Private Bag X17, Bellville, South Africa, 7535

Tel no. 021 959 2948

Email: research-ethics@uwc.ac.za

Confidentiality
All information obtained during the course of this research is strictly confidential. Data that may be reported in law or scientific journals will not include any information which identifies you as a participant in this study. Data / information will be published anonymously. No information will be disclosed to any third party without your written permission.

Informed Consent

(Actual consent form of Orthodontist where study was conducted)

Patient: ....

Date: ....

ACKNOWLEDGEMENT

I hereby acknowledge that I have read and fully understand the treatment considerations and risks presented in this form. I also understand that there may be other problems that occur less frequently than those presented, and that actual results may differ from the anticipated results. I also acknowledge that I have discussed this form with the undersigned orthodontist and have been give the opportunity to ask any questions. I have been asked to make a choice about my treatment. I hereby consent to the treatment proposed and authorize the orthodontist indicated below to provide the treatment. I also authorize the orthodontist to provide my health care information to my other health care providers. I understand that my treatment fee covers only treatment provided by the orthodontist, and that treatment provided by other dental or medical professionals is not included in the fee for my orthodontic treatment.

CONSENT TO UNDERGO ORTHODONTIC TREATMENT

I hereby consent to the making of diagnostic records, including x-rays, before, during and following orthodontic treatment, and to the above doctor(s) and, where appropriate, staff providing orthodontic treatment described by the above doctor(s) for the above individual. I fully understand all of the risks associated with the treatment.

AUTHORIZATION FOR RELEASE OF PATIENT INFORMATION

I hereby authorize the above doctor to provide other health care providers with information regarding the above individual's orthodontic care as deemed appropriate. I understand that once released, the above doctor(s) and staff has (have) no responsibility for any further release by the individual receiving this information.

CONSENT TO USE OF RECORDS

I hereby give my permission for the use of orthodontic records, including photographs, made in the process of examinations, treatment, and retention for purposes of professional consultations, research, education, or publication in professional journals.

PRACTICE ADMINISTRATION:

1. Perfect oral hygiene must be maintained at all times. Your dentist must be visited every 6 months through out orthodontic treatment. Your oral hygienist must be visited every 3 months.
2. Results can only be expected where total co-operation can be relied upon.
3. Appointments not kept will be charged according to the prescribed tariffs of the Dental Association and rescheduled between 8H00 and 13H00. Bulk SMS reminders are sent as a courtesy. Please do not reply to sms. You cannot rely on SMS reminders for keeping of appointments.
3. Emergency appointments will be made at 14h00 in the afternoon and must be strictly adhered to. Appointments for fitting the braces, taking off the braces, and long appointments will be made during the morning.

4

. A retention period of approximately 1 year follows active treatment. Consultations during this period must be strictly adhered to. The cost of the retainer, placed after active treatment, is included separately in the quoted fee.

5. You hereby acknowledge the responsibility of the account.The initial fee is due on the day of fitting the braces. Monthly debits are charged irrespective of the amounts or frequency of visits. All accounts must first be paid and your refund claimed from your Medical Aid. Interest will be charged after 30 days. Please be advised that this practice does not charge NRPL fees. See website www.doh.gov.za to determine their fees. Our tariffs are determined by the actual cost to maintain the highest standards of excellence. Accounts are sent by email on the 15th of each month. Please contact us if you do not receive it. You are responsible to let us know of any change in address and email address.

Signature of Patient/Parent/Guardian:

..

Date: ....

Signature of Orthodontist: ....

APPENDIX 2:

Data Collection Sheets

Holdaway Cephalometric Values - Before Treatment

Subjects	Group	Convexity (mm)	Lower Lip to H-Line (mm)	S.T. Facial Angle (º)	Superior Sulcus Depth (mm)	Subnasale to H-Line (mm)	U-Lip Thickness @ A Point (mm)	U-Lip Thickness @ Ver Border (mm)	H-Angle (º)	Inferior Sulcus to H-Line (mm)	Chin Thickness (mm)	Nasal Prominence (mm)	
1	1	0.7	1.2	92.8	3.6	4.8	11.3	10.5	11.9	4	11	11.8	EXTRACTION GROUP
2	1	6.8	1.8	89	1.6	4.6	12.4	9.8	23.4	4.6	10	11.6	
3	1	10	2.8	88.1	1.8	11.8	15.3	7.9	20.9	7.1	16.9	15.7	
4	1	8.9	1.5	87.9	2.8	9.5	11.3	9.8	26.3	4.4	9.5	14.9	
5	1	3.7	2.3	87.8	-0.6	7	11.9	5.9	11.9	1.9	10.4	12.5	
6	1	3.9	2.4	90.5	1.1	4.3	13.6	12.7	16.4	5.5	12.5	13.1	
7	1	3.9	-1	87.8	-0.3	1.9	11	8.1	12.1	2.7	11.1	14.7	
8	1	2.8	2.5	86.1	-0.3	3.4	12.4	8.4	14	3.4	7.8	13.8	
9	1	4.4	3.2	95.4	1.8	4.3	15.2	11.6	14	2.1	11.4	11.6	
10	1	3.4	1.3	95.1	2.7	4.6	12.9	11.5	16.2	3.5	12.9	7.4	
11	1	1.9	0.5	92.4	1.1	3.1	15.4	9.6	17.2	5.7	10.6	15	
12	1	4.2	1.8	92.2	5	10	19	14.2	20.6	7.3	11.6	5.5	
13	1	0.1	5	93.4	1.6	5.9	19.4	7.2	14.2	-0.8	11.1	10.9	
14	1	4.3	2	94	5	8	13.4	12.5	22.3	3.9	10	8	
15	1	3.7	2.2	93.4	3.9	7.1	14.6	14.1	14.6	4.5	14.1	8.4	
16	1	1.4	0.9	104.3	2.7	3.4	14.2	11.5	9.4	3.3	16.8	7.6	
17	1	2.9	2.8	91.4	2.5	2.4	13.8	12.9	16.7	2.6	11.9	8.1	
18	1	3.2	1.5	95.3	3.6	5.2	13.1	14.2	15.3	4.4	11.8	6.7	
19	1	1.4	0.7	91.1	0.7	1.1	4.9	4.2	15.5	1.6	5	3.8	
20	1	1.3	1.2	94	3.5	4.9	12.6	8.7	12.2	4.6	11	10.1	
21	1	1.4	1.6	93.1	2.9	4.1	14.9	10.8	14.6	5.3	11.9	10.3	
22	1	3.7	4	88.6	-0.5	6.7	20.1	10.3	14.7	2.1	12.2	13.1	
23	1	2.1	1.4	98.5	3.3	5.8	14.5	8	15.8	3.7	14	5	
24	1	4.5	1	94.8	3.9	9.5	14.1	12.2	16.3	2.2	13.1	9.2	
25	1	9.2	3.1	85.2	1	10.1	18	14.4	20.4	5.7	22.1	14.1	
26	2	0	-0.7	95.4	2.3	-0.7	13.6	12	6.1	5.6	14.2	12.7	NON - EXTRACTION GROUP
27	2	3.7	-2.3	97.4	1.5	1.6	16.3	12.9	12.2	5.6	15.2	14.3	
28	2	0.9	-2	92.3	3.9	8.7	16.8	13.8	15.6	6	14	8	
29	2	4.4	3.1	92	4.5	8.9	13.7	12.7	22.3	2.7	13.3	7.4	
30	2	2.3	1.4	98.4	3.6	6.2	17.3	13.3	16.2	3.6	14.5	6.2	
31	2	2.9	0	92.4	2.4	2.3	13	15.3	9.8	3.9	13.1	11.4	
32	2	4.3	2.2	95.9	3.3	4.4	15.6	10	12.9	3.5	17.3	7.9	
33	2	4.2	1.5	93.1	3.4	3.4	10.6	11.9	13.2	4.3	11.2	11.9	
34	2	1.9	1.9	91.8	4	8.7	13.3	10.4	14.5	2.4	11.4	7.5	
35	2	0.8	0	98.2	1.1	2.7	5.4	3.6	15.1	1.1	4	1.3	
36	2	3.3	0.8	92.3	0.5	2.4	14.6	9.1	15.3	4	11.7	13.4	
37	2	-1.7	0.3	98.3	0.7	-1.8	12.5	7.6	-0.1	1.5	11.9	11.1	
38	2	-1.4	0.2	91.1	3.2	2.1	13.3	11.9	9.7	7.7	8.5	17.7	
39	2	1	0	87.2	1.3	-0.4	16.4	12	11	5.8	11.8	20.6	
40	2	2.3	3.1	95.8	4.9	11.2	17	12.9	19	3.4	14.8	2.6	
41	2	2.9	0.2	93.2	1.4	0.5	13.2	11.6	12.9	5	9.2	14.9	
42	2	3	-1.9	95.7	2.5	2	14.3	13.9	15.4	6.6	9.7	13.1	
43	2	3.1	-2.1	96.4	3.5	4.1	14.4	13.7	15.4	5	10.4	12.1	
44	2	2.9	0.5	96.7	0.5	0.7	13.1	8.3	4.5	3.2	12	14.1	
45	2	4.1	0.2	80.9	2.7	6.1	16.3	14.8	18	3.7	13.2	18.3	
46	2	5.9	1.5	88.4	3.2	4.7	13.3	11.9	18.8	3.8	12	13.6	
47	2	4.9	1.4	90.5	2.8	1.9	11.9	12.7	14.6	3.9	12.6	11.8	
48	2	0.9	-0.1	99.9	3.2	2.7	14.5	11.9	9.9	4.7	11.8	7.3	
49	2	3.3	1.4	91.9	2.2	3.6	13.2	8.7	13.3	1.8	10.5	13.4	
50	2	1.9	1.3	88.7	2.3	3.9	16.1	7.4	10.1	2.9	10.5	16.8	
51	2	4.9	1.5	92	1.6	1.6	13.7	10.9	15.4	5.1	11.1	15.9	
52	2	0.8	-0.1	92.1	1.9	1.9	16.5	11.2	10.2	3.8	12.9	10.8	
53	2	-3.5	-3	79.8	-1.5	-3.2	16.6	9.3	3	7.3	11.2	23.3	
54	2	2.4	1.5	89.5	2.9	1.5	14.4	15.7	13.9	3.8	10.3	15.6	
55	2	3.3	0	86.5	1.1	3.7	17	13.1	15.6	6.2	11.2	19.4	
56	2	-1.9	0.6	92.3	1.1	1.5	15.7	10.4	6.9	2.9	12.8	15.7	
57	2	2.9	-1.6	98.2	1.8	1.7	15.1	13.3	9.2	6.2	14.4	9.5	
58	2	2.3	1.7	95	4.5	7.7	16.7	14.2	18.8	2.6	13.4	7.4	
59	2	3.2	-1.9	94.2	1.7	3.6	16.4	13	12.7	6.4	14.7	14.4	
60	2	0.3	1.4	91.2	1.2	-1.4	12.5	10.8	7.7	4.6	9.9	15.7	

Holdaway Cephalometric Values - After Treatment

EXTRACTION GROUP

Subjects	Group	Convexity (mm)	Lower Lip to H-Line (mm)	S.T. Facial Angle (º)	Superior Sulcus Depth (mm)	Subnasale to H-Line (mm)	U-Lip Thickness @ A Point (mm)	U-Lip Thickness @ Ver Border (mm)	H-Angle (º)	Inferior Sulcus to H-Line (mm)	Chin Thickness (mm)	Nasal Prominence (mm)
1	1	1.6	2.4	94	3.9	5.5	11.4	11.3	12.7	4.6	12.3	10.5
2	1	4.7	-0.5	87.1	1.3	4.7	14	13.6	19.7	5.2	9.7	14.5
3	1	9.5	0.5	83.8	0.7	7.8	9.5	11.4	16.4	4.5	13.5	16.7
4	1	6.3	3.2	88.5	1.9	5.2	12.1	11	21.9	3.2	8.3	17.5
5	1	1.5	2.2	86.3	-0.7	4.3	12.8	7.3	10.1	2.9	9.7	15.3
6	1	4.2	2.9	87	0.7	3.2	13	12.8	14.5	3	12.3	19.1
7	1	2.2	1.6	92.1	1	0.6	13.2	12.2	11.2	4.4	11.2	14
8	1	0.8	1.6	89.2	1.2	3.6	15	10.6	15.2	4.4	8.6	16.7
9	1	1.9	2.1	89.2	-0.8	3	17.3	13	12.6	3.4	12.9	17.5
10	1	3.8	0.6	93.1	2.8	3.7	12.4	14	14.3	4	14.1	9.6
11	1	-2.6	0.1	94.2	2.2	2	16	12.9	12.5	5.9	10.4	16.4
12	1	1.9	1.5	95.7	3.6	3.6	12.4	10.3	15.8	4.7	10	9.8
13	1	3.5	3.9	97.5	3.9	6.8	12	9.9	13.7	0.7	11.4	9.1
14	1	3.7	2.4	95.1	4.5	5.5	12.7	12.6	19.7	3.5	10.2	9.4
15	1	2.7	1.8	96.1	5.1	7.5	11.3	13.3	11.4	5.3	14	8.5
16	1	0.9	-0.4	100.8	4.4	5	11.9	10.4	10.3	4.4	12.7	7.8
17	1	3.6	0.4	90.7	2.4	4.1	13.6	14.2	18	3.6	9.9	10.7
18	1	3.7	1.2	103.5	5.7	5.3	12	15	14.4	5.7	13.1	4.1
19	1	1.8	1.2	93.8	1.2	2.5	16.1	13.2	14	4.4	14.4	10.7
20	1	0.5	0.2	93.9	3.4	4.8	12	10	10.9	4.9	10.9	12
21	1	0.7	1.1	96.2	3.4	5.6	14.7	14.8	16.4	4.9	11.1	8.8
22	1	1.5	0.3	90.8	0.6	5.3	16.4	11.8	12.8	4.2	11.6	14
23	1	3.3	-0.3	100.3	4.8	6.5	11.9	12.4	15.5	4	14.1	4.6
24	1	2.8	0.4	93.1	3.6	7	11.3	11.5	13.6	2.2	12.5	9.9
25	1	5.8	1	92.6	2.2	8.6	16.6	16	18.8	4.8	15.9	10.3

NON - EXTRACTION GROUP

Subjects	Group	Convexity (mm)	Lower Lip to H-Line (mm)	S.T. Facial Angle (º)	Superior Sulcus Depth (mm)	Subnasale to H-Line (mm)	U-Lip Thickness @ A Point (mm)	U-Lip Thickness @ Ver Border (mm)	H-Angle (º)	Inferior Sulcus to H-Line (mm)	Chin Thickness (mm)	Nasal Prominence (mm)
26	2	0	0.9	97.4	3.2	1.4	12.9	9.8	7.7	4.7	13.8	12.3
27	2	2.2	-2.5	99.6	1.8	0.3	15.3	10.4	11.1	7.1	13.6	13.5
28	2	0.1	-0.4	96.8	4.3	8.1	18.4	13.9	14	5.3	14.2	6.3
29	2	4.9	3.7	93.4	4.7	8.7	14.2	12.4	20.8	4	11.9	7.5
30	2	-0.4	2.3	95.6	4.4	5.8	16.3	11	14.4	3.5	12.5	8.1
31	2	0.8	1.5	88.5	2.7	2.1	13	14.2	10.9	3.3	12.1	13.4
32	2	6.8	2.7	100.8	5.2	5.8	10.8	11.6	13.3	4	17.6	6.2
33	2	1.7	3	94.2	4	5	13.1	13	14.4	5.2	12.3	11.3
34	2	0.6	1.9	94.6	4.1	8.9	15.7	12.2	14.5	3	13.4	7.7
35	2	7.4	0.6	97.8	5	8.9	13.8	14.2	16.5	3.9	16	7.7
36	2	1.7	1.9	97	3	4	15.8	11	16.7	4	11.7	11.1
37	2	-2.2	1.7	94.4	3.6	4.9	15	11.5	11.8	3.7	12.1	8.9
38	2	-1.3	1.5	92.7	4.2	3.5	13	12.6	10.3	7.8	9.8	15
39	2	-1.8	1.9	90.1	1.2	1.3	18.9	13.4	11.1	6.4	12.2	18.5
40	2	2.8	2.1	95.1	5.8	11.6	14.4	11.8	18.4	3.7	13.6	3.2
41	2	-0.8	2.6	91.9	0.9	0.8	16.2	9.3	10.4	4.2	10.3	19.5
42	2	2.9	0	93.7	0.4	0.7	14.9	9.4	13.4	5	9.4	14.5
43	2	1	0.5	93.2	4.3	7	16.7	15.2	18.5	5.5	11.1	11.4
44	2	1.3	0.9	92.3	1.1	3.1	13.8	8.5	7.5	2.4	11.5	14.6
45	2	1	0.4	87.8	3.1	6.5	16.8	13.3	15.1	4	12.1	15.8
46	2	4	1.4	96.2	3.7	4.5	12.1	10.2	15.7	3.6	11	10.9
47	2	1.5	2.6	93.8	1.8	3	15.1	10.9	15.9	2.5	10.5	12.1
48	2	0.1	0.6	98.6	4.5	3.9	14.2	12.5	13.1	5.7	12.2	8.9
49	2	0	3.1	92.3	3.4	5.4	14.5	10.7	15.5	2.7	9.5	11.3
50	2	3.7	2.5	90.5	3	6.1	13.2	8.6	14.9	3.8	10.6	14.1
51	2	2.8	2.5	91.3	1.8	2.4	13.7	9.3	16.1	3.6	10.8	16.1
52	2	-1.7	0.3	91.3	2.4	3.1	18.3	11.8	11.9	4.1	13.5	11
53	2	-7.9	-1.2	92.4	2.8	1.8	18.6	14.2	6.9	8.8	11.7	15.4
54	2	0.1	0.1	89.3	2.9	3.1	14.6	11.7	12.8	4.4	10.9	16.2
55	2	1.8	0.7	86.5	1.3	4.1	15.6	11	13.6	5.3	10.8	20.2
56	2	0.8	0.7	93.9	1.8	2	14.9	11.7	11.4	3.6	13	13.3
57	2	3.3	1.1	90.3	1.7	3.7	16.4	13.1	12.8	3.8	14	14.2
58	2	2.6	3.1	97	5.1	6.9	15.2	13.4	14.7	1.7	14.6	7.5
59	2	1.2	0.5	95.5	0.9	-1.8	14.2	9.2	7	3.2	14.1	18.6
60	2	0.5	-1.1	90.3	0.8	-0.1	13.6	10.6	8.5	4.7	11.1	14.3

APPENDIX 3:

BMREC Approval letter

UNIVERSITY of the WESTERN CAPE

OFFICE OF THE DIRECTOR: RESEARCH
RESEARCH AND INNOVATION DIVISION

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01 December 2017

Dr JC Julyan
Faculty of Dentistry

Ethics Reference Number: BM17/10/22

Project Title: Soft tissue profile changes in patients treated with non-extraction versus second premolar extraction protocols – using the Damon system.

Approval Period: 24 November 2017 – 24 November 2018

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

PROVISIONAL REC NUMBER -130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

APPENDIX 4

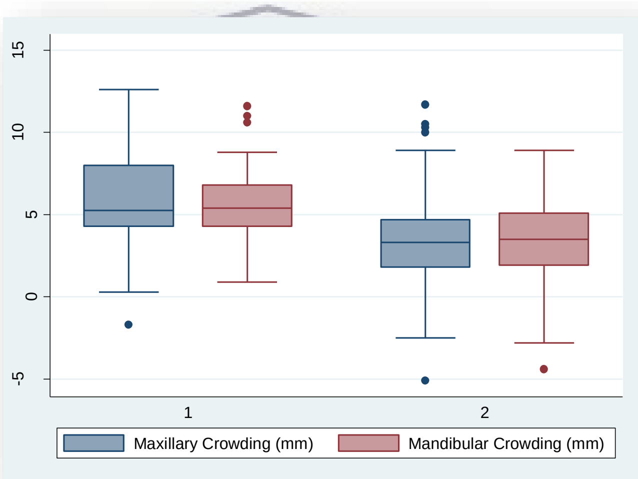
Propensity Score Matching

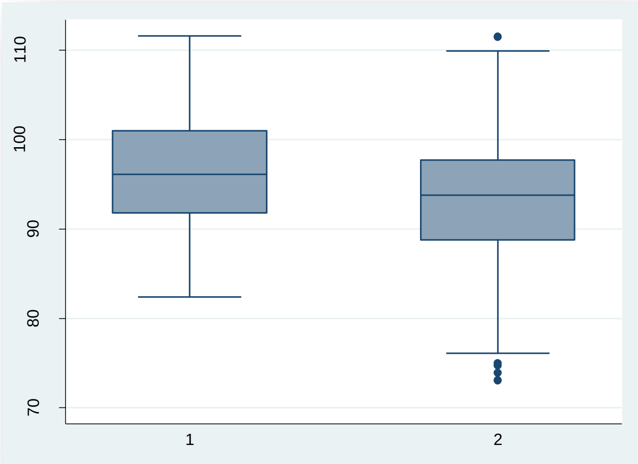
Propensity score matching of extraction and non-extraction cases

Matching steps

1. Setup indicators for meeting the inclusion criteria for each of the three measurements.
2. Setup a consolidated indicator using all three criteria. Thus, all participants irrespective of type meet the criteria
3. Used this selected subset across both types to perform a matching analysis
4. Check the outcome of the matching.

Results





Differences between types before matching

2-sample t-test to confirm and quantify difference before matching

. ttest MaxillaryCrowdingmm, by(type)

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
1	42	5.861905	.4095684	2.654306	5.034765	6.689045
2	213	3.349765	.174415	2.545503	3.005955	3.693575
combined	255	3.763529	.1705476	2.723426	3.427662	4.099397
diff		2.51214	.4327931		1.659803	3.364476

diff = mean(1) - mean(2) t = 5.8045

Ho: diff = 0 degrees of freedom = 253

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0

Pr(T < t) = 1.0000 Pr(|T| > |t|) = 0.0000 Pr(T > t) = 0.0000

. ttest MandibularCrowdingmm , by(type)

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
1	42	5.707143	.3528611	2.286801	4.994525	6.41976
2	213	3.5723	.1554247	2.268349	3.265925	3.878676

```
---------+--------------------------------------------------------------------
combined |     255    3.923922    .1504008    2.401709     3.62773    4.220113
---------+--------------------------------------------------------------------
    diff |            2.134842    .3834773                1.379628    2.890057
------------------------------------------------------------------------------
    diff = mean(1) - mean(2)                                      t =   5.5671
Ho: diff = 0                                     degrees of freedom =      253

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

<u>. ttest LowerincisorinclinationDegre , by(type)</u>

Two-sample t test with equal variances

```
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      42     96.0119    1.054944    6.836816     93.8814    98.14241
       2 |     213    93.31972    .4974965    7.260723    92.33904    94.30039
---------+--------------------------------------------------------------------
combined |     255    93.76314    .4539456     7.24893    92.86916    94.65711
---------+--------------------------------------------------------------------
    diff |            2.692186    1.214533                .3003035    5.084069
------------------------------------------------------------------------------
    diff = mean(1) - mean(2)                                      t =   2.2166
Ho: diff = 0                                     degrees of freedom =      253
    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9862         Pr(|T| > |t|) = 0.0275          Pr(T > t) = 0.0138
.
```

- **Significant difference for all three variables**

Inclusion indicators

1. **generate max_crit=0**

   replace max_crit=1 if MaxillaryCrowdingmm>=4 & MaxillaryCrowdingmm<=8

2. **generate man_crit=0**

   replace man_crit=1 if MandibularCrowdingmm >=4 & MandibularCrowdingmm <=8

3. **generate lower_crit=0**

   replace lower_crit=1 if LowerincisorinclinationDegre>=85 & LowerincisorinclinationDegre<=110

generate select=0

replace select=1 if max_crit==1 & man_crit==1 & lower_crit==1

Marginal selection

1. **tab max_crit type, row**

```
+----------------+
| Key            |
|----------------|
|   frequency    |
| row percentage |
+----------------+

           |        type
  max_crit |         1          2 |     Total
-----------+----------------------+----------
         0 |        11        144 |       155
           |      7.10      92.90 |    100.00
```

1	31	69	100
	31.00	69.00	100.00
Total	42	213	255
	16.47	83.53	100.00

2. **tab man_crit type, row**

man_crit	type 1	2	Total
0	8	131	139
	5.76	94.24	100.00
1	34	82	116
	29.31	70.69	100.00
Total	42	213	255
	16.47	83.53	100.00

3. **tab lower_crit type, row**

lower_crit	type 1	2	Total
0	5	27	32
	15.63	84.38	100.00
1	37	186	223

```
           |     16.59      83.41 |    100.00
-----------+----------------------+----------
     Total |        42        213 |       255
           |     16.47      83.53 |    100.00

. tab select type, row

           |         type
    select |         1          2 |     Total
-----------+----------------------+----------
         0 |        17        178 |       195
           |      8.72      91.28 |    100.00
-----------+----------------------+----------
         1 |        25         35 |        60
           |     41.67      58.33 |    100.00
-----------+----------------------+----------
     Total |        42        213 |       255
           |     16.47      83.53 |    100.00
```


- **60 participants meet all three the inclusion criteria 25 treated and 35 untreated**

Comparison of selected subgroup

. ttest MaxillaryCrowdingmm if select==1, by(type)

Two-sample t test with equal variances

```
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      25       5.204    .2332009    1.166005    4.722697    5.685303
       2 |      35        5.62    .1766542    1.045101    5.260995    5.979005
---------+--------------------------------------------------------------------
combined |      60    5.446667    .1429011    1.106907    5.160722    5.732611
---------+--------------------------------------------------------------------
    diff |               -.416    .2871959               -.9908851    .1588851
------------------------------------------------------------------------------
    diff = mean(1) - mean(2)                                      t =  -1.4485
Ho: diff = 0                                     degrees of freedom =       58

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0764         Pr(|T| > |t|) = 0.1529          Pr(T > t) = 0.9236
```


. ttest MandibularCrowdingmm if select==1, by(type)

Two-sample t test with equal variances

```
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      25       5.692    .2482552    1.241276    5.179626    6.204374
       2 |      35    5.574286    .1903708    1.126249    5.187406    5.961166
---------+--------------------------------------------------------------------
```

```
combined |     60    5.623333    .1506177     1.16668    5.321948    5.924719
---------+--------------------------------------------------------------------
    diff |           .1177143    .3077429               -.4983002    .7337287
------------------------------------------------------------------------------
    diff = mean(1) - mean(2)                                      t =   0.3825
Ho: diff = 0                                     degrees of freedom =       58

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.6483         Pr(|T| > |t|) = 0.7035          Pr(T > t) = 0.3517
```

. ttest LowerincisorinclinationDegre if select==1, by(type)

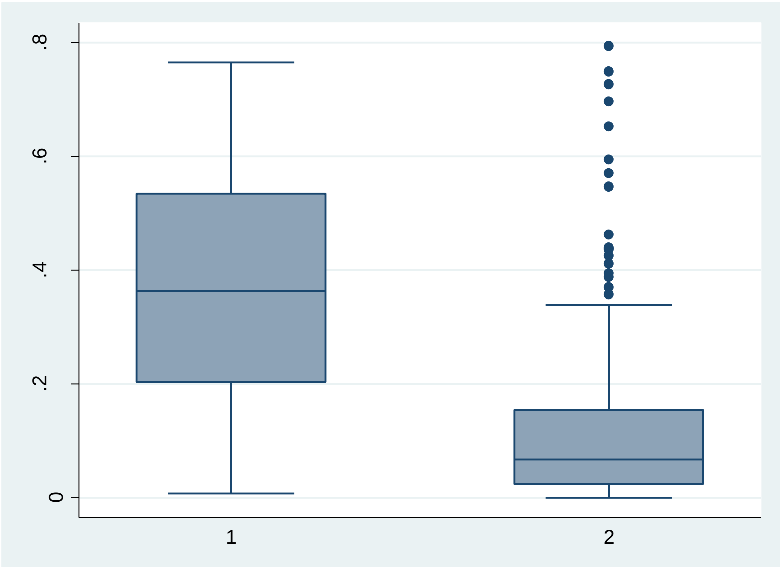
```
Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      25        97.4    .9593922    4.796961    95.41991    99.38009
       2 |      35    94.88857     1.07561    6.363396    92.70267    97.07447
---------+--------------------------------------------------------------------
combined |      60      95.935    .7555812    5.852707    94.42309    97.44691
---------+--------------------------------------------------------------------
    diff |            2.511429    1.510169               -.5115024     5.53436
------------------------------------------------------------------------------
    diff = mean(1) - mean(2)                                      t =   1.6630
Ho: diff = 0                                     degrees of freedom =       58
    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9491         Pr(|T| > |t|) = 0.1017          Pr(T > t) = 0.0509
```

- There are no differences between the treated and untreated groups
- Inclusion criteria thus a good first step of matching.

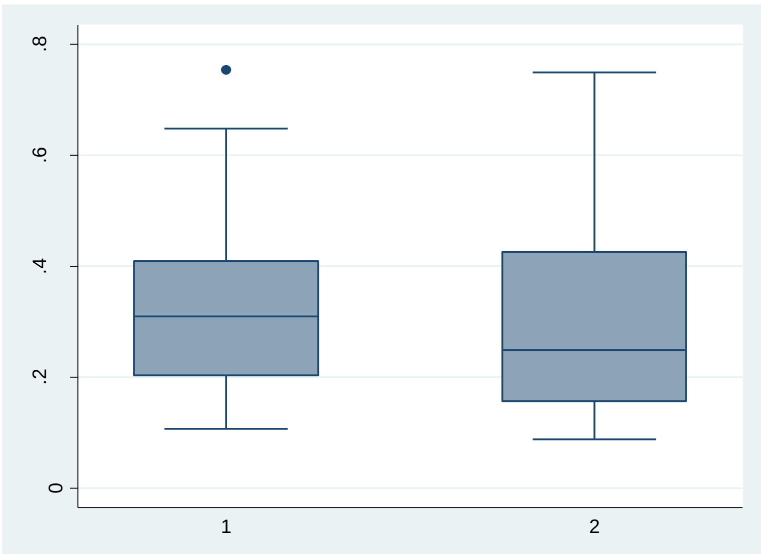
Confirm this selection with a matching analysis

Mahalanobis-distance kernel matching was use based on the three measurements as well as the propensity score of the variables for the probability to belong to the same group. The 60 participants were used for this.

Propensity score of all participants by type



Propensity score for those 60 meeting the inclusion criteria



Comparison

. ttest _KM_ps if select==1, by(type)

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
1	25	.3336106	.0334103	.1670516	.2646551	.4025661
2	35	.3048011	.0292285	.1729182	.2454016	.3642005
combined	60	.316805	.0219042	.1696695	.2729748	.3606353
diff		.0288095	.0446513		-.0605698	.1181889

diff = mean(1) - mean(2)   t = 0.6452

Ho: diff = 0   degrees of freedom = 58

Ha: diff < 0   Ha: diff != 0   Ha: diff > 0

Pr(T < t) = 0.7393   Pr(|T| > |t|) = 0.5213   Pr(T > t) = 0.2607

Formal matching using the select group

Multivariate-distance kernel matching   Number of obs = 60

Kernel = epan

Treatment : type = 1

Metric : mahalanobis

Covariates: MaxillaryCrowdingmm MandibularCrowdingmm ...

Matching statistics

	Matched			Controls			Band-
	Yes	No	Total	Used	Unused	Total	width
Treated	25	0	25	35	0	35	1.4356
Untreated	35	0	35	25	0	25	1.5711
Combined	60	0	60	60	0	60	.

Based on the inclusion criteria no further cases are not matched

The comparison of the treatment outcome will therefore be done between the selected 25 extraction and 35 non-extraction cases.

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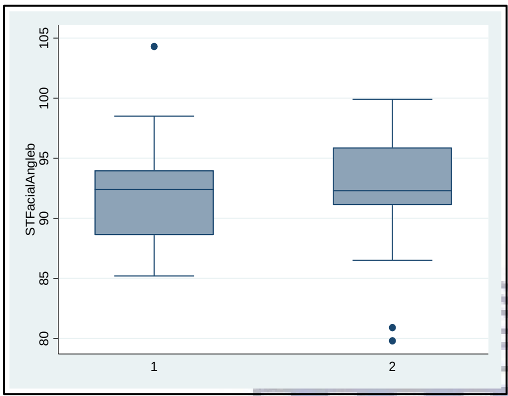
APPENDIX 5

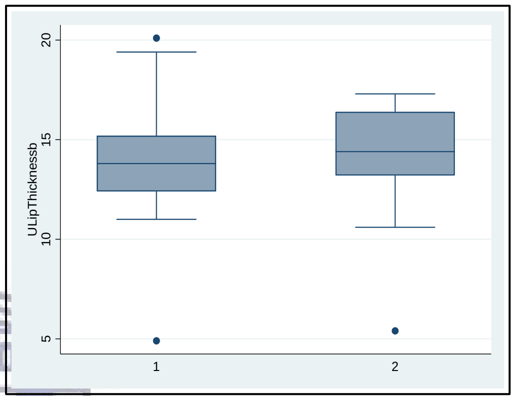
Boxplots of the results for both groups

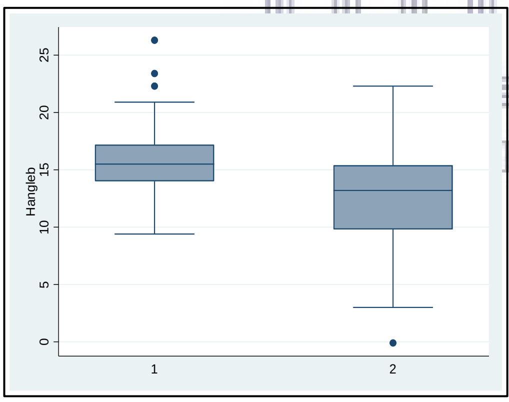
Before treatment

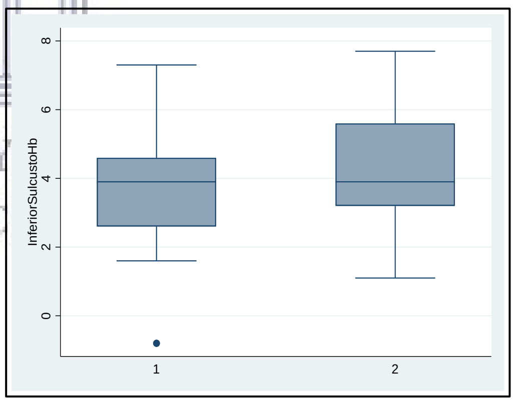
1. **Extraction Group**

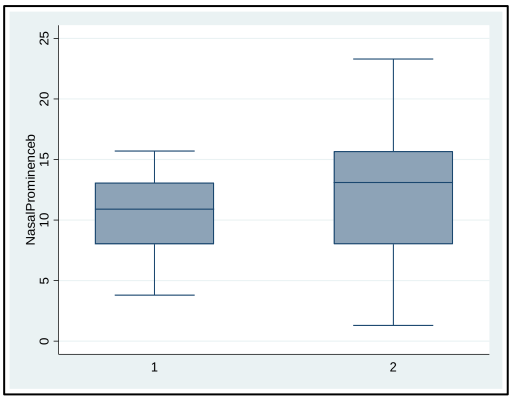
2. **Non-Extraction group**

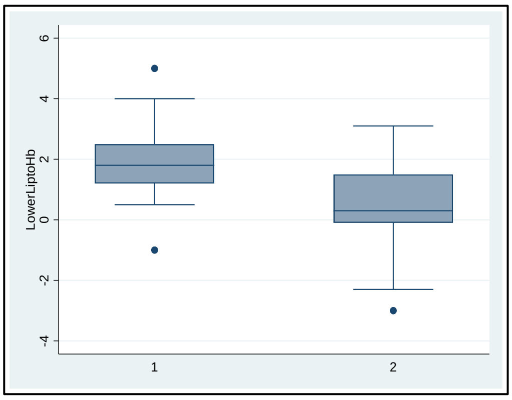


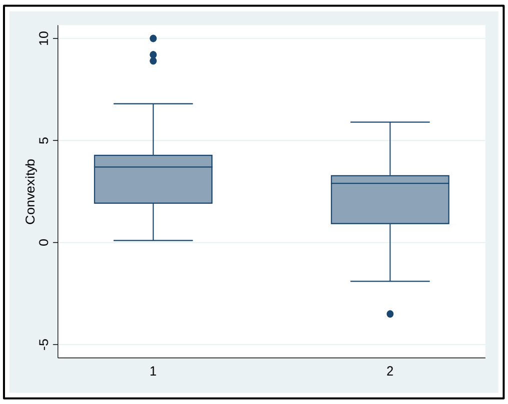


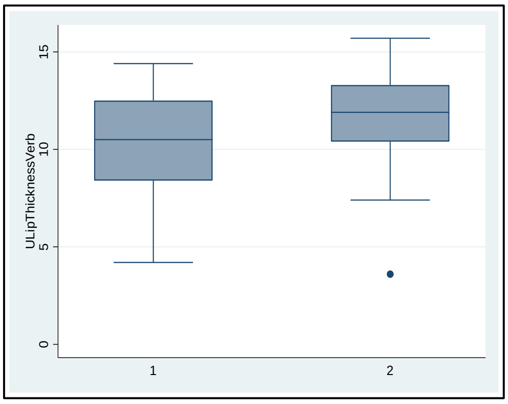


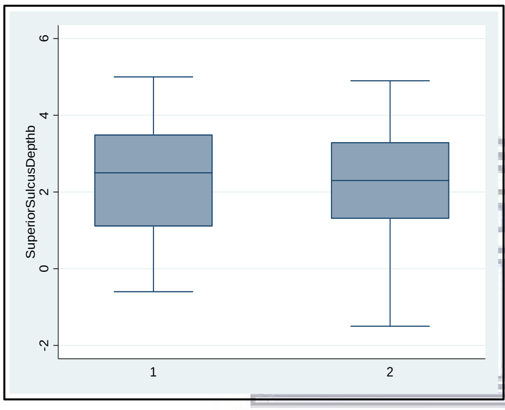


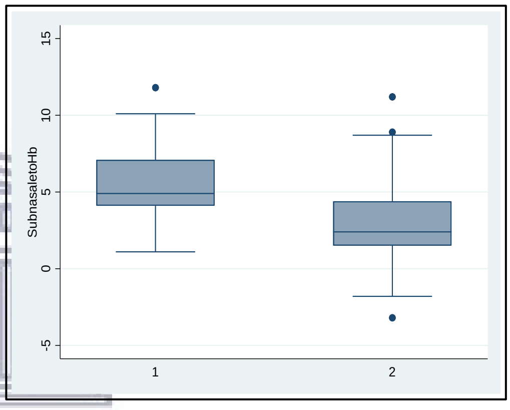


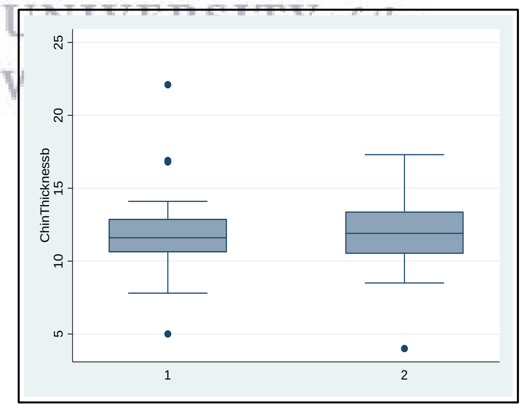



Convexityb
-5
0
5
10
1
2


ULipThicknessVerb
0
5
10
15
1
2


SuperiorSulcusDepthb
-2
0
2
4
6
1
2

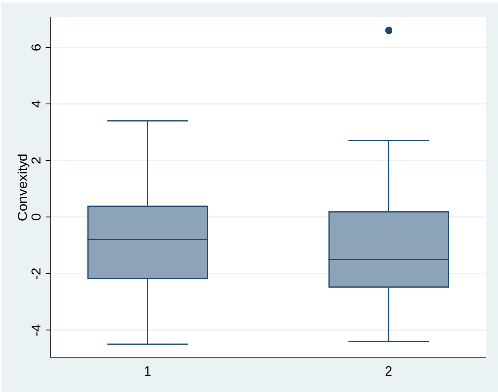

SubnasaletoHb
-5
0
5
10
15
1
2

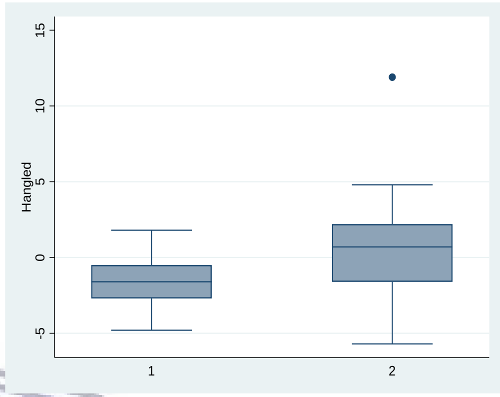

ChinThicknessb
5
10
15
20
25
1
2

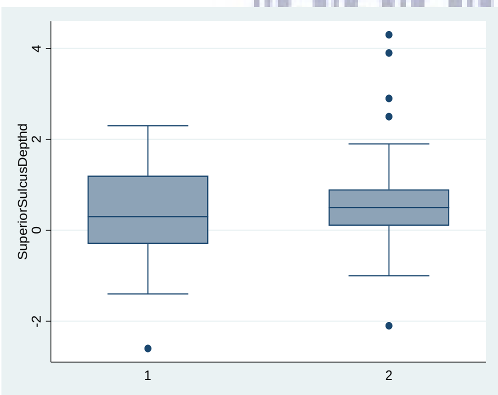
Changes from before to after treatment

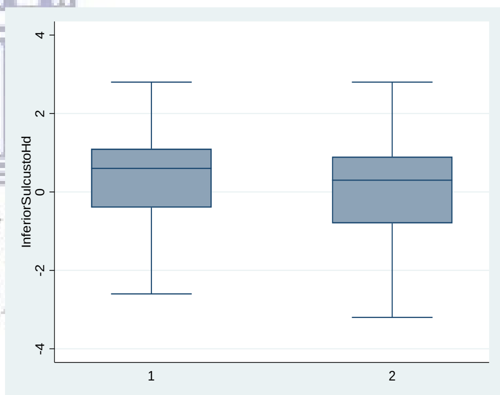
1. **Extraction Group**

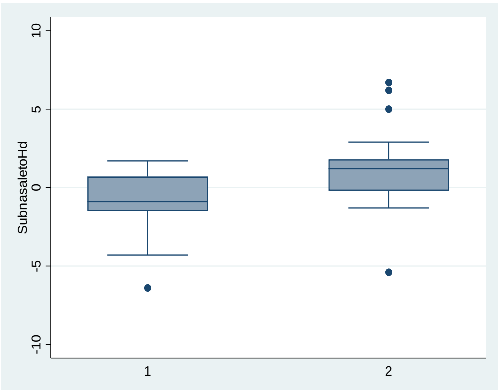
2. **Non-Extraction group**

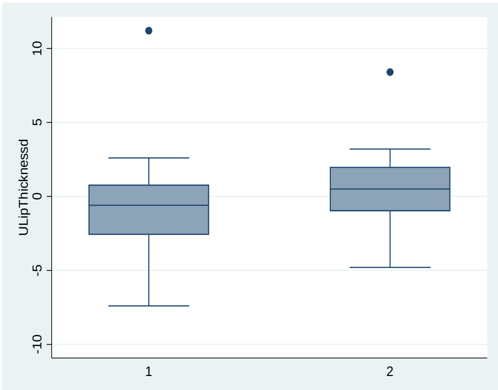


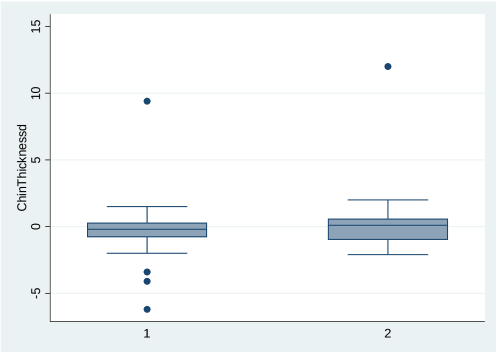


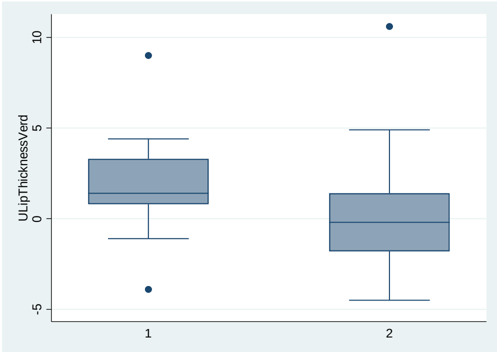


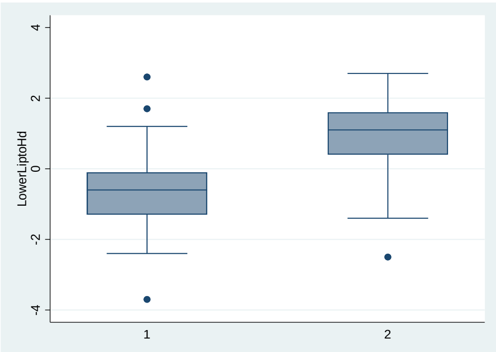


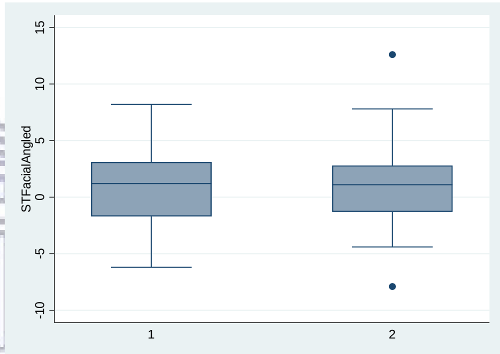


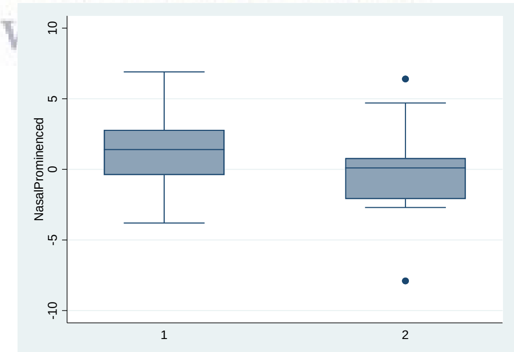



ChinThickness
15
10
5
0
-5
1
2


ULipThicknessVerd
10
5
0
-5
1
2


LowerLiptoHd
4
2
0
-2
-4
1
2


STFacialAngled
15
10
5
0
-5
-10
1
2


NasalProminenced
10
5
0
-5
-10
1
2