A radiographic comparison of the proclination of mandibular incisors between Class II extraction and non-extraction cases using the Damon® self-ligating system

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WESTERN CAPE

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A minithesis submitted in partial fulfilment of the requirements for the degree of MChD in the Department of Orthodontics, University of the Western Cape,

Cape Town, South Africa

2020

KEYWORDS

Class II Division 1

Class II Division 2

Damon® technique

Lower incisor position

Lower incisor proclination

Non-extraction orthodontic treatment

Passive self-ligating system

Premolar extractions

ABSTRACT

Introduction

The stable position of the mandibular incisors, and the extent to which their spatial position may be changed in the sagittal plane, represents a key point in determining orthodontic treatment goals and objectives. According to the equilibrium theory, the mandibular incisors lie in a narrow zone of stability that is governed by pressure from the lips, cheek, tongue and periodontium. Proclining the mandibular incisors more than 2 mm leads to instability because of an increase in lip pressure. The magnitude of incisor proclination therefore determines aesthetics, stability and function.

Contemporary discussion and debate have focused on the influence of bracket type on the biology and rate of orthodontic tooth movement. One such bracket system is the Damon® bracket, a passive self-ligating twin bracket appliance that uses heat-activated superelastic arch wires. The Damon® philosophy asserts that the bracket produces biologically friendly "light forces", which create a new force equilibrium. By acting as a ''lip bumper", the perioral muscles reduce the proclination of the mandibular incisors.

Aim

The aim of this study was to compare the magnitude of mandibular incisor proclination in full fixed appliance mechanotherapy with the Damon® self-ligating bracket system in Class II Division 1 and Division 2 malocclusion treated with and without premolar extractions.

Materials and Methods

The sample consisted of the pre-treatment and post-treatment lateral cephalometric films of 82 patients, 54 female and 28 male, aged 10 to 15 years, who were treated using the Damon® PSL bracket. All the patients in this study were selected from the patient archives of a private dental practitioner. After selection, the patient pool was further stratified into an extraction group that comprised 24 females and 12 males and a non-extraction group that comprised 30 females and 16 males. The images were interpreted by two examiners that had been calibrated to evaluate the lower incisor inclination and procumbency.

Results

Inter- and intra-examiner reliability were quantified by intraclass coefficients and showed moderate (0.5–0.75) to excellent agreement (values greater than 0.9). The mandibular incisors were proclined in both the extraction and non-extraction samples, as indicated by the measurement mandibular incisor to pogonion (L1–A-Pog) (°) (extraction sample = 3.73 and non-extraction sample = 10.21), the Frankfort mandibular incisor angle (FMIA) (extraction sample = -3.11 and non-extraction sample = -8.48) and incisor mandibular plane angle (IMPA) (extraction sample = 2.26 and non-extraction sample = 8.06). The mandibular incisors were also protruded during treatment, as indicated by the L1–A-Pog (mm) (extraction sample = 0.4 and non-extraction sample = 3.0). Overall post-treatment non-extraction cases showed a larger increment in mandibular incisor inclination (L1–A-Pog), linear measurement (L–A-Pog mm), IMPA and FMIA, compared to extraction cases, which were statistically significant ($p < 0.0001$).

The largest absolute mean difference between the extraction and non-extraction groups was observed in the L1–A-Pog angle [6.47 (SE=1.09)], followed by the IMPA angle [5.80(SE=1.01)], the FMIA angle [5.36(SE=1.09)] and the L1–A-Pog (mm) [2.60(SE=0.49)]. The L1–A-Pog (mm) exhibited the smallest absolute mean difference between the extraction group and the non-extraction group.

Conclusion

In this study it was observed that both extraction and non-extraction treatment with the Damon® appliance in growing skeletal Class II subjects exhibited protruded and proclined mandibular incisors. This contradicts the lip bumper theory of Damon. Mandibular incisor compensation is an accepted goal of treatment to camouflage the sagittal maxillo-mandibular relationship.

DECLARATION

I declare that “A radiographic comparison of the proclination of mandibular incisors between Class II extraction and non-extraction cases using the Damon® self-ligating bracket system” is my own work, that it has not been submitted for any degree or examination at any university, and that all the sources I used or quoted are indicated and acknowledged in complete references.

Full name: Leeren Warren Walton Date: 11 December 2020

Signature of Candidate

ACKNOWLEDGEMENTS

I wish to express my gratitude to:

Almighty God, my heavenly Father, for the opportunity to study Orthodontics and for providing me with the strength to complete my thesis and this course.

Professor AMP Harris, my supervisor, for her guidance and mentorship during the completion of my thesis.

Dr M Coetsee, co-supervisor with Prof Harris, for allowing me the use of his patient records as well as for all his advice on the study design and data collection.

Dr F Kimmie, for her help with the statistical analysis and results of this study.

Dr R Carim, for her invaluable support with the write-up of this study.

The consultants in the Department of Orthodontics, University of the Western Cape (UWC), for their guidance throughout my orthodontic training.

My fellow registrars, for inspiring me to be the best version of myself.

DEDICATION

This thesis is dedicated to my late parents, Fred and Florence Walton. Thank you for all you have done for me. Your teachings will forever live in my heart.

This thesis is also dedicated to my son, Zachary Leeran Walton. You are my motivation, inspiration and strength. I strive to be the best I can possibly be, simply because you are part of my life.

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LIST OF ABBREVIATIONS

A-Pog	Line from point A to Pogonion
ASLB	Active self-ligating bracket
CoS	Curve of Spee
FH	Frankfort Horizontal
FMIA	Frankfort mandibular incisor angle
ICC	Intraclass coefficients
IMPA	Incisor mandibular plane angle
L1	Mandibular incisor
L1/Bperp	Lower incisor to point B perpendicular
L1/NB	Lower incisor in relation to a plane from nasion to point B
NA	Line from nasion to point A
NB	Line from nasion to point B
OTM	Orthodontic tooth movement
PSLB	Passive self-ligating bracket
SD	Standard deviation
SE	Standard error

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CHAPTER 1

INTRODUCTION

In the introduction to the chapter, the following factors are presented.

1.1 Malocclusion

Malocclusion of the teeth is due to an interplay between environmental and genetic factors. Edward Angle (1900), the father of orthodontics, was of the opinion that orthodontic treatment could produce stable, ideal occlusions without tooth extraction. He was of the conviction that aesthetics and stability were dependent on adherence to the line of occlusion. The line of occlusion, as described by Angle, is a catenary curve that passes through the central fossa of each maxillary molar and across the cingulum of the maxillary canine and incisor teeth. This line also passes along the buccal cusps and incisal edges of the lower teeth (Proffit et al, 2012). Malocclusion therefore occurs where this line is typically distorted.

1.2 Extraction and non-extraction controversies

The extraction/non-extraction pendulum has swung back and forth. A study conducted by the University of North Carolina in the USA that tabulated the extraction frequencies at the university in 1953, 1963 and 1993 showed a dramatic 40% rise and fall in extraction rates between 1953 and 1993 (Proffit, 1994). The increase in frequency of the first premolar extractions was due to the search for greater stability and the decline was due to the concern about the impact of extractions on facial aesthetics. Studies in this regard showed that extraction did not guarantee stability, and raised the concern that extractions were related to distal displacement of the mandible, which in turn caused temporomandibular dysfunction and obstructive sleep apnoea as well changes in bracket systems and techniques (Proffit, 1994).

Contemporary discussion and debate are focusing on the influence of bracket type on the biology and rate of orthodontic tooth movement ?. One such bracket system is the Damon® bracket, a passive, self-ligating twin bracket appliance that uses heat-activated superelastic archwires. The Damon® philosophy asserts that the bracket produces biologically friendly "light forces" that create a new force equilibrium. By acting as a lip bumper, the perioral muscles reduce the proclination of the mandibular incisors (Damon, 1998b). This allows the teeth to align and the arch form to reshape itself as a result of the "Frankel-like" effect on the alveolar bone and surrounding tissues. Furthermore, it was claimed that this new arch form was determined by the body and not by the bracket system or the orthodontist (Damon, 2005).

Expansion of the arch form without tipping of the incisors has been demonstrated in computed tomography (CT) scans. It has been alleged that this is related to the design of the bracket, the torque control that it provides as well as the wire sequence (Badawi et al, 2008; Morina et al, 2008). However, studies have also shown that mandibular incisor procumbency and expansion of the buccal segments occur when crowding is alleviated during non-extraction treatment (Pandis, Polychronopou and Eliades, 2007; Weinberg and Sadowsky, 1996).

A comparison between the Damon® 2 bracket system and a conventional edgewise bracket showed that crowding was resolved by a combination of mandibular incisor proclination and transverse expansion, irrespective of the bracket system that was used (Nogueira et al, 2018).

Proponents of premolar extractions are of the conviction that facial harmony is affected by marked dental crowding and protrusion. The maxillary incisors support the lips, therefore lip procumbence is a reflection of the extent of maxillary incisor protrusion.

Furthermore, the maxillary incisors provide the anterior guiding slope for protrusive excursions of the mandible. The spatial position of the maxillary incisor is therefore related to the position of the mandibular incisor (Merrifield, 1996).

The stable position of the mandibular incisors, and the extent to which their spatial position may be changed in the sagittal plane, represents a key point in determining orthodontic treatment goals and objectives. According to the equilibrium theory, the mandibular incisors lie in a narrow zone of stability that is governed by the pressure from the lips, cheek, tongue and periodontium. Proclining the mandibular incisors more than 2 mm leads to instability, because of an increase in lip pressure (Ackerman and Proffit, 1997). The magnitude of incisor proclination therefore determines aesthetics, stability and function (Jerrold, Accordnero and Chay, 2019).

However, a study that evaluated mandibular incisor positions in untreated Scandinavian children with clinically ideal occlusion observed that the mandibular incisors were 2.5 mm in front of the A-Pog plane (SD 1.7) and 4.9 mm (SD 1.8) anterior to the NB line, thus concluding that the lower incisors were more proclined and procumbent (Platou and Zachrisson, 1983). In contrast Bjork (1963) observed relatively upright incisors in Scandinavian children. Furthermore, no significant difference in the long-term stability between extraction (Gardner and Chaconas, 1976; Little, Wallen and Riedel, 1981; Little, Riedel and Artun, 1988) and non-extraction cases were observed. This has further weakened the argument against proclination.

Previous studies focused primarily on the Damon® appliance in patients with a Class I malocclusion (Pandis et al, 2007; Nogueira et al, 2018). Therefore the aim of this research was to assess if mandibular incisor proclination occurred in a subset of Class II growing patients who were treated by either an extraction or a non-extraction protocol with the use of the Damon® SLB bracket. Teeth respond to forces and moments and are not aware of the bracket type. Furthermore, space should be available so that the mandibular incisor teeth can be placed in a stable position (Vaden, Williams and Goforth, 2018).

CHAPTER 2

LITERATURE REVIEW

2.1 Malocclusions

Three primary treatment approaches for the correction of a skeletal Class II malocclusion associated with mandibular deficiency have been described by Proffit and Ackerman (1994). These are growth modification, dental compensation and surgical correction. The treatment options depend on the patients' maxillomandibular disharmony, the patient's growth potential as well as the necessity of extractions.

Growth modification uses headgear or functional appliances to improve or correct apical base discrepancies and reduce overjet through dentoalveolar effects (Proffit et al, 2012). A combined orthodontic-orthognathic correction is indicated when the sagittal maxillomandibular discrepancy has an ANB angle greater than 6° (Daniels et al, 2017). It has been observed that, in patients with an initial ANB angle of 6° and greater, orthognathic surgery consistently allowed for improvement in facial profile aesthetics (Shelly et al, 2000).

When the basal bone of the maxilla deviates from its expected growth pattern, the remaining craniofacial structures compensate to establish a normal incisor relationship and to mask the basal bone discrepancy. Correction is achieved through posterior movement of the maxillary dentition and simultaneous anterior movement of the mandibular dentition, thereby contributing to retroclination of the upper incisor, and proclination of the lower incisors (Isaacson, Worms and Speidel, 1976).

Patients with moderate to severe skeletal Class II malocclusions often exhibit compensated maxillary and mandibular incisors (Casko and Shepherd, 1984) that necessitate mandibular premolar extractions to decompensate the proclined mandibular incisors prior to orthognathic surgery (Potts et al, 2009).

In contrast, when orthopaedic or orthodontic camouflage is the selected treatment option, the treatment protocol may involve extraction or non-extraction. In a non-extraction treatment protocol, mandibular incisor compensation is an accepted goal of the treatment to camouflage the sagittal maxilla–mandibular relationship (Janson et al, 2006; Sangcharearn and Ho, 2007).

Orthodontic camouflage with extraction of the maxillary first premolars may lead to over-retraction of the maxillary incisors and an increase in the nasolabial angle. At the same time, correction of Class II malocclusions by using Class II elastics can lead to excessive proclination of the mandibular incisors, in turn leading to instability of the mandibular incisors as well as stress on the mandibular periodontium (Mihalik, Proffit and Phillips, 2003).

It has been observed that, in an adolescent, no more than half of the changes needed to correct a Class II malocclusion would be achieved by differential jaw growth. Both orthodontic camouflage and growth modification necessitates mesial displacement of the mandibular dental arch (Proffit et al, 2012). Patients with residual mandibular growth may present with a reduction in the skeletal discrepancy that mitigates the extent of incisor compensation at the end of treatment (Daniels et al, 2017).

The cortical plate of the mandible and the dimensions of the anterior alveolus represent a limitation to orthodontic tooth movement (OTM). The anterior limit of the mandibular incisors was first highlighted by Ackerman and Proffit (1997) and is a factor that should be established before treatment commences. Transgressing these boundaries may lead to iatrogenic sequelae such as dehiscences, fenestrations or instability of the mandibular incisors (Handelman, 1996). More recently it was reported that in 25 per cent of cases where mandibular incisors were proclined in excess of 10°, there was an association with the onset of recession (Pernet et al, 2019).

2.2 Measurements used to evaluate changes in lower incisor position

Literature relating to orthodontic issues is replete with cephalometric norms that are used to assess mandibular incisor inclination and position. Tweed (1954) related the lower incisor to the Frankfort Horizontal (FH), while Downs (1948) measured the incisor relationships in children with excellent occlusion and reported that the angular means were 135.4° for the interincisal angle and 91.4° for the mandibular incisor to the mandibular plane. Margolis (1943) reported that the incisor mandibular plane angle (IMPA) ranged from 90° to 93°. These norms were based on dento-cranial relations, as opposed to dento-facial relations (Williams, 1969).

Ricketts (1960) advocated the use of the A-Pog plane in locating the final position of the mandibular incisor. As many as 1 000 treated orthodontic cases were evaluated in his study. It was observed that the average location of the mandibular incisor was 0.5 mm ahead of the A-Pog line with an angle of 21°. Ricketts termed the A-Pog line the “denture plane” (Ricketts, 1960).

While Ricketts (1960) recommended the use of both the linear and angular measures of the lower incisor to the A-Pog plane (L1–A-Pog), Williams (1969) was of the opinion that the linear relationship to the A-Pog line was of greater importance to lip balance and denture stability than the angulation of the lower incisor to the A-Pog plane. He termed this line the “diagnostic line”, proposing that to ensure favourable aesthetics, the incisal edge of the lower incisor should lie at or near the diagnostic line.

In a study of 400 random malocclusions, it was observed that in high-angle cases (ccclusal plane to mandibular plane > 20 degrees), the mandibular incisor was approximately 3.1 mm anterior to the A-Pog line, while in low-angle cases, the mandibular incisor was an average of 1.3 mm ahead of the A-Pog line (Schudy, 1963). Orthodontic treatment can change point A and mandibular growth can alter the pogonion. Furthermore, these changes can alter the A-Pog plane.

During the 1930s it became clear that even with excellent occlusion, orthodontic results were unsatisfactory if this is achieved at the expense of proper facial proportions (Proffit et al, 2012). One of Angle’s students, Charles Tweed (1954), was not happy with the facial imbalance found in the greater majority of the patients he had treated without premolar extractions. Tweed’s (1954) clinical studies of the cases he had treated before inspired him to re-treat over 100 of his non-extraction patients with premolar extractions. In doing this, he found an improved soft tissue balance as well as better facial proportions in comparison with the resultant bimaxillary protrusion, which was the usual aftermath of non-extraction treatment advised by Angle (Tweed, 1966).

Tweed (1954) was concerned about the position of the lower incisor in the basal bone of the mandible. He found that when he re-evaluated his treated cases who appeared to have facial harmony and compared them with non-orthodontic patients with good facial balance, he found that the position of the lower incisor in relation to the lower border of the mandible should be at an angle of 90°+-5°. He recommended that the IMPA should form an angle between 85° and 95° with the mandibular plane if the angle of the mandibular plane to the FH is in the 22° to 29° range. Tweed (1954) also measured the mandibular incisor to the FH found that patients with a FMIA of 65° presented with good facial aesthetics.

Ricketts et al (1981) on the other hand focused on the A-Pog plane. The norms attached to the A-Pog plane are based on the mandibular incisors being at + 1 mm (± 2 mm) and 22°(24°). Ellis and McNamara (1986) reported the most generally used measures for lower incisor position as being the long axis of the mandibular incisor to the A-Pog plane (L1–A-Pog). This measurement gives orientation of the angular and linear measurements of the lower incisor. It should be kept in mind that the A-Pog plane relates the mandibular incisor to the skeletal development of the maxilla and the mandible. It is therefore best to use measurements related to the lower incisor, which is not too distant from the object being measured. Searching for predictors of long-term stability, it was observed that for every millimeter increase in L1–A-Pog, incisor irregularity increased by 0.16 mm, when all other variables remained constant (Franklin et al, 2013).

In addition, the lower incisor can be measured to the line between nasion to point B or NB line (L1/NB), as well as point B perpendicular (L1/Bperp), which is the distance between the facial aspect of the mandibular incisor and a perpendicular erected from the mandibular plane to point B. The measurements found to be the most accurate were IMPA and L1/Bperp (Ellis and McNamara, 1986).

2.3 Extractions and Mandibular Incisor Change

The anterior limits of the mandibular dental arch are described by both the intercanine width and the incisor position in the antero-posterior plane. The introduction of cephalometrics made it possible to ascertain the position of the mandibular incisor and has subsequently become a valuable tool when assessing a malocclusion (Williams, 1969).

Various norms, as previously described, in respect of the position of the mandibular incisor have been proposed to predict the stability of orthodontic treatment. If stability of treatment is the end result, the mandibular incisor can only be moved within a small range (Proffit et al, 2012).

Premolar teeth are located between the anterior and posterior segments of the dental arch and are therefore most commonly extracted to allow for the relief of crowding or the correction of an unacceptable interincisal relationship (Ong and Woods, 2001).

The correlation between anchorage potential and root surface area has been well documented in the existing literature. Therefore, the extraction protocol that is followed would affect the amount of anterior segment retraction (Steyn, Du Preez and Harris, 1997). Shearn and Woods (2000:351–361) stated that "…all other things being equal, the amount of incisor retraction will be less the further posteriorly in the arch an extraction is located" and that "even with second premolar extraction, some retraction of the lower incisors may occur, but most of the space closure will be by mesial movement of the lower molars."

Steyn et al (1997) found that, relative to the nasion-pogonion line (N-Pog), the mandibular incisors were retracted by 2.1 mm in subjects with mandibular first premolar extractions and by 1.4 mm where there were second premolar extractions. Another study observed that the mandibular incisors were retroclined by 1.3 mm in patients treated with first premolar extractions and by 0.8mm in those patients who were treated with second premolar extractions. Furthermore, the mandibular incisors were proclined in 22% of patients and retroclined in 65% of patients. The average change in the L1 relative to the N-Pog line was 1.02 mm. No significant gender disparity existed in any of these cases (Al-Nimri, 2003).

Shearn and Woods (2000) compared three subjects with variation in incisor position due to different premolar extraction protocols being followed. In the first individual the incisors were retracted significantly, the second individual exhibited proclination and in the third individual no change in incisor position was observed. It was concluded that incisor retraction was proportional to the magnitude of crowding. Greater retraction of the lower incisors occurred with greater residual space. Pretreatment crowding of greater than 5 mm resulted in forward incisor movement.

Furthermore, it was observed that the mean changes in the positions of the mandibular incisors in relation to the A-Pog plane varied according to the extraction sequence. However, this was not reflected in any change of the mandibular incisors in relation to their position on the bone (corpus axis at suprapogonion). Therefore, the effect of growth must be given due consideration as there is interaction between the mandibular incisor movement, sagittal and vertical movement of the chin as well as the effect of orthodontic treatment at point A.

The researchers Shearn and Woods (2000) also observed anchorage loss with greater mesial movement of the mandibular molars than incisal retraction when the extraction protocol consisted of lower second premolars compared to the extraction of lower first premolars. However, these authors conceded that specific extraction patterns did not guarantee certain amounts of incisor retraction nor lower molar mesial movement (Shearn and Woods, 2000).

In a study conducted by Luppanapornlarp and Johnston (1993), 62 patients were recalled after an average of 15 years post-treatment, when it was observed that neither extraction nor non-extraction Class II cases differed from their initial presentation. This study evaluated profile changes in either "clear-cut" extraction cases or "clear-cut" non-extraction cases. The extraction patients appeared more protrusive before treatment as well as after treatment. On the other hand, the "clear-cut" non-extraction patients who appeared retrusive before treatment still appeared retrusive after treatment. Furthermore, the extraction group indicated 2.8 mm of incisor retraction compared with the non-extraction group (Luppanapornlarp and Johnston, 1993).

Weinberg and Sadowsky (1996) looked at borderline Class I malocclusion cases that were treated through non-extraction. It was observed that 52% of the crowding resolution was due to expansion in the buccal segments and proclination of the incisors. The lower were incisors advanced by 2.1 mm and proclined by 6.1° (Weinberg and Sadowsky, 1996).

When assessing mandibular incisor stability, Paquette, Beattie and Johnston (1992) reported more post-retention incisor irregularity in the non-extraction group as compared to patients who had been treated by extraction of four premolars. In contrast, other studies reported that the extraction group exhibited significantly more crowding than the non-extraction group (Glenn, Sinclair and |Alexander, 1987; Kahl-Nieke, Fischbach and Schwarze, 1996). Furthermore, no significant difference in long-term stability between extraction and non-extraction cases were observed (Gardner and Chaconas, 1976; Little, Wallen and Riedel, 1981; Little, Riedel and Artun, 1988). Therefore, even if the incisors are positioned in accordance with orthodontic norms, it does not guarantee long-term stability (Vajaria et al, 2011).

2.4 Damon® self-ligating bracket system

A passive self-ligation system was introduced by Dwight Damon in the mid-twentieth century (Noguiera et al, 2018). Since its introduction the philosophy has undergone a few evolutionary changes, as have bracket designs over the years. Damon's (1998a) philosophy is based on the theory of employing light forces and by asserting low friction would ultimately produce biologically more stable results. This is a concept which came to light in the mid-nineteenth century, when Storey published an article on the force in orthodontics and its relation to tooth movement (Storey, 1952). Storey (1952) concluded that approximately 200 g force are needed for a cuspid retraction that would render the posterior segment of the dentition stable.

In addition Storey (1952) also found that with higher forces, approximately 500 g, the posterior segment would start to move mesially and the anterior segment would remain stable. This is thought to be due to hyalinisation of the periodontal ligament following the occlusion of blood vessels due to the high forces and therefore the necessary cells, fibroblasts, osteoblasts and osteoclasts cannot be mobilised to the desired location to effect bone resorption on the pressure side and bone deposition on the tension side (Storey, 1973a, 1973b). Begg (1956) expanded on the differential force theory in orthodontics when he popularised the Begg system.

Damon’s philosophy in the mid 1990s of utilising low forces and combining it with the low friction bracket system was the motivation for his creation of this revolutionary orthodontic system (Damon, 1998a). This philosophy asserts that biologically friendly light forces do not overpower the oral musculature. Damon (1998b) argues that the arch form aligns through posterior expansion and that the perioral musculature, namely the orbicularis oris and the mentalis muscle, act as lip bumper that reduces advancement of the mandibular incisors.

Furthermore, Damon (1998a) claimed that SLBs produce less friction during sliding mechanics than their conventionally ligated counterparts. The bracket provides a broader smile, shows enhanced patient comfort and is healthier for the periodontium as the light forces prevent proclination and recession. However, these claims have not been unanimously accepted nor have they been substantiated in the literature (Miles, Weyant and Rustveld, 2006).

Use of the Damon® system also results in fewer visits to the orthodontist and studies have claimed that treatment becomes more comfortable for the patients. This could be ascribed to the reduced need for extractions, which ultimately also results in decreased anxiety and less pain for the patient (Bach, 2009). In a study by Yamaguchi et al (2009) as cited by Harradine (2013), the author stated that decreased levels of the neuropeptidase substance P were found in the gingival crevicular fluid of patients treated with self-ligation compared to patients treated with conventional systems. Substance P is an indicator for associated pain and inflammation as a result of orthodontic forces (Harradine, 2013). Other authors have reported that SLBs offer reduced amounts of friction when moving teeth, allowing OTM to be achieved using smaller forces, thereby causing less damage to the periodontium, with subsequent decreased root resorption and improved mechanics. This contributes to reducing total treatment time (Nogueira et al, 2018).

2.4.1 Frictional effects on Damon® self-ligating system

A review of the literature revealed that SLBs have shown reduced friction during sliding mechanics in comparison to conventionally ligated systems. Damon® brackets in particular have displayed reduced friction when compared to ligated brackets (Vajaria et al, 2011).

The elimination of elastomeric modules and replacement with slots reduces the amount of time a patient spends in the dentist’s chair. Self-ligating brackets were developed on the foundation that eliminating elastomeric ligatures allowed for better sliding mechanics due to the friction-free environment that was created by this system (Eberting, Straja and Tuncay, 2001). Friction is classified into two types, static friction and kinetic friction. When a force is applied to an object, static friction occurs until the force is large enough to overcome the initial resistance to movement of the object. Kinetic friction comes into play once the object is in motion; and it opposes continuation of the movement (Burrow, 2009). Birnie (2008) states that static friction measured in vitro is more relevant to conventional brackets than SLBs. Friction is negligible in this case when compared to other fixed appliance systems.

The kinetic friction measured for the passive self-ligating bracket (PSLB) has also been reported to be the lowest among four different bracket systems (Mah, 2002).

2.4.2 Treatment mechanics with Damon® self-ligating system

Damon (1998b) reports that there is no need for anchorage devices in the Damon® system as a minimal amount of force is utilised to correct the malocclusion (Birnie, 2008). Intra-oral expansion appliances such as the W-arch or quad-helix are not required with this appliance system as the arches expand naturally with the copper NiTi wires used in this technique. Damon further states that there is no need for extractions to facilitate orthodontic mechanics (Damon,1998b).

Damon (1998b) moreover posits that with his passive self-ligation system there is no proclination of the incisors. The rationale for this statement is derived from the fact that the forces are kept very low when applied to the teeth. According to Damon (1998b), the lips assist with limiting anterior movement of the dentition and the tongue assists with the posterior expansion. The Damon (1998a) philosophy justifies this by referring to the biological light forces, which do not overpower the perioral musculature, which comprises the orbicularis oris and mentalis muscles. Instead, Damon claims that the arch form straightens by taking the path of least resistance, namely posterior expansion, instead of forcing proclination of the incisors (Damon, 1998a; Nogueira et al, 2018). In addition, Damon (1998b) also states that the perioral muscles act as a lip bumper that reduces the forward movement of the incisors. Although, in extraction cases, the teeth take the path of least resistance, Damon affirms that with non-extraction cases the light force mechanics with .014″ copper nickel titanium wires produce posterior expansion (Damon, 2005). According to the cephalometric tracings produced by Damon in his 1998 article, the incisors maintain their anteroposterior positions, nor does the mandibular intercanine width change significantly with his system (Damon, 1998; Nogueira et al, 2018).

2.4.3 Post-treatment changes

Numerous factors may play a role in post-treatment changes in the dentition. Factors include mandibular incisor dimensions, alteration of the original arch form, periodontal and gingival tissues, neuromusculature, growth, environmental factors, post-treatment tooth positioning, and establishment of functional occlusion. Furthermore, researchers Melrose and Millett (1998) listed third molar development in addition to the original element of malocclusion.

Nogueira et al (2018) conducted a study radiographically to determine the anteroposterior change in the position and inclination of the upper and lower incisors and to evaluate transverse (inter-canine, inter-premolar, and inter-molar) dimension changes in both arches treated with the Damon® system. Damon

(1998b) highlighted that mandibular incisors are usually advanced and proclined during treatment of Class I Type 1 malocclusion cases that have been treated non-extraction, using conventionally ligated brackets. A comparison between the Damon® 2 and the conventional edgewise bracket systems revealed that the two groups both experienced an increase in mandibular incisor proclination and mandibular transverse dimension (Nogueira et al, 2018).

Furthermore, the mandibular incisors were about 1.5º less proclined in cases treated with SLBs compared to cases treated with conventional brackets. Proclination and advancement of the lower incisors are findings associated with studies that analyse the alleviation of crowding (Nogueira et al, 2018). Pandis et al (2007) observe a proclination of 7° to 8° associated with the alleviation of crowding with the use of the Damon® 2 system. Although, in this case, proclination was evident in both the maxillary and mandibular arches, the proclination of the lower incisors was more pronounced compared to the maxillary incisors (Vajaria et al, 2011). Proclination of the incisors as well as an increase in intercanine distance using both self-ligating as well as conventional brackets during initial stages of treatment was reported (Fleming et al, 2009; Pandis et al, 2010).

Romero-Delmastro et al (2017) conducted a study to compare the patterns of dento-alveolar changes that take place after non-extraction treatment. The sample included Class I malocclusions with moderate crowding treated with conventional, passive self-ligating bracket (PSLB) and active self-ligating bracket (ASLB) systems. These researchers (2017) found no significant differences between PSLBs and conventional systems in the patterns of the changes in any of the variables they studied. Although all three groups showed significant increases in the arch width of maxillary and mandibular premolars, the ASLB group appeared to control the mandibular incisor position more successfully than the other two groups. The latter finding should neveretheless be interpreted with caution as the clinical significance of less than a millimetre or a couple of degrees could be limited in some cases (Romero-Delmastro et al, 2017).

Scott et al (2008) conducted a study to compare the efficiency of mandibular tooth alignment and the clinical effectiveness of a SLB and a conventional, preadjusted edgewise orthodontic bracket system. The extraction protocol included mandibular first premolars. Pre-treatment crowding was alleviated by an increase in intercanine width, decreased arch length and proclination of the mandibular incisors. This was observed in respect of both the Damon® 3 and conventional bracket systems. It is therefore evident that proclination of the mandibular incisors is a frequent occurrence with non-extraction treatment and may even occur in extraction treatment cases. Therefore, the assertion by Damon (1998) that the Damon® passive self-ligation system does not result in proclination of the incisors cannot be substantiated (Scott et al, 2008; Sayed, Gaballah and El Shourbagy, 2016).

Vajaria and colleagues (2011) showed that maxillary incisor changes were not statistically significant compared to the changes that were observed in the mandibular arch. Nogueira et al (2018) therefore focused their attention on the mandibular incisors, which is also what this current study focused on.

2.5 Torque expression of self-ligating brackets

Torque is defined as "a moment generated by the torsion of a rectangular wire in the bracket slot" (Rauch, 1959, cited in Morina et al, 2008). Torque depends on the wire torque stiffness, bracket design, the wire/slot play and the mode of ligation. Effective values for torquing moments are in the range 1.0 to 2.0 Ncm (Burstone, 1966; Feldner et al, 1994).

In orthodontics, correct buccolingual inclination of the anterior teeth enables good occlusal relationships. Adequate torque of the maxillary anterior teeth is essential in establishing proper anterior guidance, an aesthetic smile line, and a Class I canine and molar relationship. Every 5° of anterior inclination generates approximately 1 mm of arch length (O'Higgins, Kirschen and Lee, 1999). Under-torqued maxillary anterior teeth affect arch length and space requirements while under-torqued posterior teeth have a constricting effect on the maxillary arch (Gioka and Eliades, 2004).

Torque expression occurs by gradual increase in the archwire diameters. However, there is some play between the archwire and the bracket slot as the diameters of the final working archwire never reach the full dimension of the bracket slot (Badawi et al, 2008).

Cash et al (2004) reported that the conformation and size of the slot appear to be one of the factors that most influence the effectiveness of torque. In their study, these researchers measured 11 commercially available bracket systems in a 0.022″ dimension for accuracy. Results indicated that all bracket slots were oversized, regardless of whether they expressed self-ligation or conventional ligation. This implies that the clearance between the wire and the slot are larger than stated by the manufacturers. Clinicians should be aware that torque expression may be reduced as a result of the inadvertent use of brackets with oversized slots (Cash et al, 2004).

The basic advantages of SLBs involve the elimination of elastomeric modules or stainless steel ligatures. Self-ligating brackets provide a number of favourable effects during treatment, the most important being the achievement of consistent wire engagement. This occurs without the undesirable force decay of elastomeric modules and aids in maintaining the constantly active status of engaged wires (Pandis, Strigou and Eliades, 2006).

Effective values for torquing moments are in the range of 1.0 to 2.0 Ncm (Burstone, 1966; Feldner et al, 1994). In contrast, a study by Franco et al (2015) found that the effectiveness of torque responded differently for each bracket type. Torque expression was evaluated among six different bracket types, including ASLB and PSLB as well as conventional bracket types. It was found that, for clinical effects, torque of 5 Nmm first appeared in Damon® 3MX, followed by Roth Max®, In-Ovation R®, Roth® SLI, Portia® and Bioquick®. For a torque of 20 Nmm, Damon® 3MX self-ligating brackets were the first to be expressed, followed by In-Ovation R®, Roth Max®, Portia®, Roth SLI® and Bioquick® (Franco et al, 2015). In a study by Badawi et al (2008), the authors stated that the range of torque was expressed at 15° to 31° of torsion for the active self-ligating brackets, and at 22.5° to 34.5° of torsion for the passive self-ligating brackets (Badawi et al, 2008).

Franco et al (2015) concluded that the mode of ligation between the wire/bracket (ASL, PSL or conventional bracket systems with elastomeric modules) did not influence final torque expression. The latter is dependent on the interaction between the wire and the bracket chosen to be used during orthodontic treatment.

2.6 The use of Class II elastics to correct a Class II malocclusion

Class II elastics are among the armamentarium to treat Class II malocclusions. They exhibit mainly dentoalveolar effects (71.1%), and 18.9% skeletal effects (Janson et al, 2013). It was observed that with Class II elastics, the mandibular first molars moved 1.2 mm forward, causing a loss of mandibular anchorage, and the mandibular incisors became proclined (Melstrell et al, 1986). The overjet was shown to be reduced by 5.8 mm and the overbite reduced by 3.0 mm. Mandibular growth surpassed maxillary growth by 1.1 mm. There was an increase in the lower anterior face height by an average of 5.0 mm (Nelson, Hansen and Hägg, 1999). Orthodontic treatment led to a clockwise rotation of the occlusal plane, which showed a tendency to return to the original condition later. It was concluded that Class II elastics are effective in correcting Class II malocclusions, although their effects are predominantly dentoalveolar (Janson et al, 2013).

When Class II elastics were compared to Class II correctors no differences were found in the changes produced by these appliances. A systematic review concluded that in the long term there are no significant differences between the treatment effects produced by fixed functional appliances and Class II elastics. Both treatment protocols camouflage a Class II malocclusion with dentoalveolar effects (Janson et al, 2013).

CHAPTER 3

AIM AND OBJECTIVES

3.1 Aim

The aim of this study was to compare the amount of proclination of the mandibular incisors in Class II extraction and non-extraction cases treated with the Damon® self-ligating system measured on lateral cephalometric radiographs.

3.2. Objectives

1. To measure the pre-treatment mandibular incisor inclination in Class II Division 1 non-extraction and extraction cases.
2. To measure the post-treatment mandibular incisor inclination in Class II Division 1 non-extraction and extraction cases.
3. To measure the linear change in mandibular incisor position between pre-treatment and post-treatment in Class II Division 1 non-extraction and extraction cases.
4. To compare the pre-treatment to the post-treatment mandibular incisor inclination in Class II Division 1 non-extraction and Class II extraction cases.
5. To compare the pre-treatment to the post-treatment linear change in the mandibular incisor position in Class II Division 1 non-extraction and extraction cases.

CHAPTER 4

MATERIALS AND METHODS

4.1 Study Design

The study was a cross-sectional study which comprised investigation of digital lateral cephalometric radiographs obtained from the archives of a private orthodontic practitioner (MC) in Cape Town, South Africa.

4.2 Sample size and sampling strategy

The sample size estimation was based on the convenience sampling technique. The sample population included growing individuals between the ages of 10 and 15 years of age at the start of treatment. The patients were furthermore categorised using their date of birth, which ranged from the year 2000 to 2008.

The Dolphin Imaging 11.7 Software of a private orthodontic practitioner in Cape Town was used to determine the number of patients who were classified as Class II patients. The Class II molar relationship was either a full-cusp Class II or an end-to-end, as determined from the pre-treatment study models that were taken in maximum intercuspation.

Patients were treated orthodontically using Damon® Q brackets from ORMCO, with a .022" x .028" slot and a standard torque prescription in the mandibular arch. Maxillary bracket torque was variable and differed from patient to patient according to individual torque needs. Once a patient’s dentition had been levelled and aligned, a .019" x .025" stainless steel arch wire was used in the mandibular arch during

Class II correction with 3.5 oz (Fox) elastics. Each patient was treated to achieve Class I occlusion. The mean amount of time from initiation to completion of treatment was about 20 months and 2 months.

The study population comprised two groups, the extraction group (Group A) and the non-extraction group (Group B). The extraction group included patients who had been treated with variable extraction protocols, namely extraction of upper first and lower second premolars (4/5), upper and lower first premolars (4/4) and upper and lower second premolars (5/5).

Initially the sample comprised 52 non-extraction cases, which included 34 females and 18 males, while the extraction sample comprised 39 individuals, of whom 26 were females and 13 were males. Therefore, the total sample size was 91 patients. During data collection, the final numbers of the participants in this study were reduced. For the non-extraction sample, the final number of subjects included in the study were 30 females and 16 males, with a total of 46 non-extraction patients. The extraction sample comprised 36 patients, which included 24 females and 12 males.

The reason for the reduction in the sample size was ascribed to an insufficient number of records that met the inclusion criteria. Some of the patients in the initial sample pool appeared to have been transfer cases taken over from other provinces in South Africa. The records that accompanied these transfer cases did not comply with the inclusion criteria identified for the study's design. The initial radiographic records differed in terms of magnification, operator, patient positioning and x-ray machine, to name a few reasons, contributing to their exclusion from this study. The final total sample size was 82 patients.

4.3 Inclusion criteria

4.3.1 Growing male and female patients between the ages of 10 and 15 years.

4.3.2 Full orthodontic treatment records, including good quality lateral cephalograms. at the beginning and end of treatment.

4.3.3 Angle Class II Division 1 malocclusions.

4.4 Exclusion criteria

4.4.1. Patients 16 years and older.

4.4.2. Patients who have had prior orthodontic therapy.

4.4.3. Patients presenting with skeletal Class III malocclusions.

4.4.4. Patients presenting with skeletal Class I malocclusions.

4.4.5. Patients who required combined orthodontic–orthognathic surgery.

4.4.6. Patients who had previously had functional appliances or fixed appliances.

4.5 Image acquisition

Lateral cephalometric radiographs were taken at three points: pre-treatment (T0), in progress and post-treatment (T1). The cephalograms for each patient were traced by the principal researcher (LW), who used Dolphin Imaging 11.7 software.

T0 lateral cephalometric radiographs were traced to measure pre-treatment lower incisor position while T1 tracings were used to evaluate post-treatment incisor position.

Four angular measurements and one linear measurement were used for this study. These are described in Table 1 and Table 2.

The principal researcher (LW) selected and retraced a random sample of 10 lateral cephalograms one month after the original tracings to test for intra-rater reliability of the tracings and measurements. The oral hygienist at the private dental practice independently selected 10 numbers from 1 to 80 to achieve a random selection. The main researcher (LW) and the orthodontist in private practice (MC) achieved inter-rater reliability, following the same procedure as outlined, two weeks after the intra-rater reliability assessments were done.

Table 1: Angular cephalometric measurements to identify incisor position

Angular cephalometric measurements	
FMIA	This describes the inclination of the L1 in relation to the Frankfort Horizontal (FH) plane (Po-Or). This angle is a significant indicator of balance in the lower face. Standard is 68° if the FMA is 22°–28°.
IMPA	Angle between mandibular plane and L1. This angle establishes the position of the lower incisor to the mandibular plane. The standard is 88°.
FMA	Indicates the direction of mandibular growth, and has a range of 22°–28° when there is a normal growth pattern.

Table 2: Cephalometric landmarks to identify incisor position

Angular and linear cephalometric measurements	
L1–A-Pog (°)	L1 inclination in relation to A-Pog plane.
L1–A-Pog (mm)	Distance (in the horizontal plane) between L1 incisal tip to A-Pog plane.

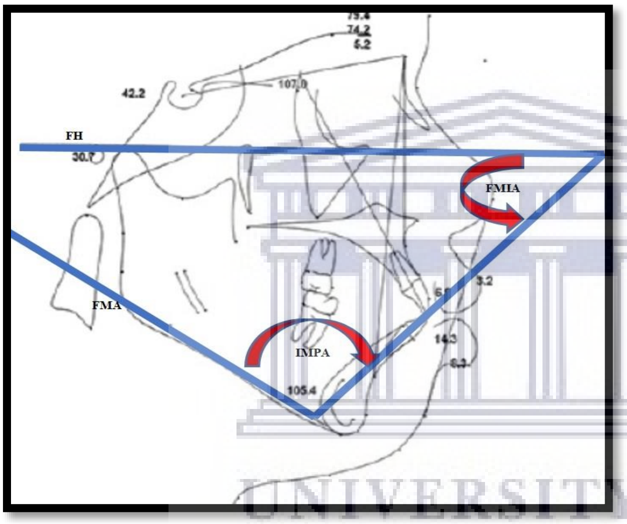

Figure 1: Cephalometric landmarks to identify incisor position

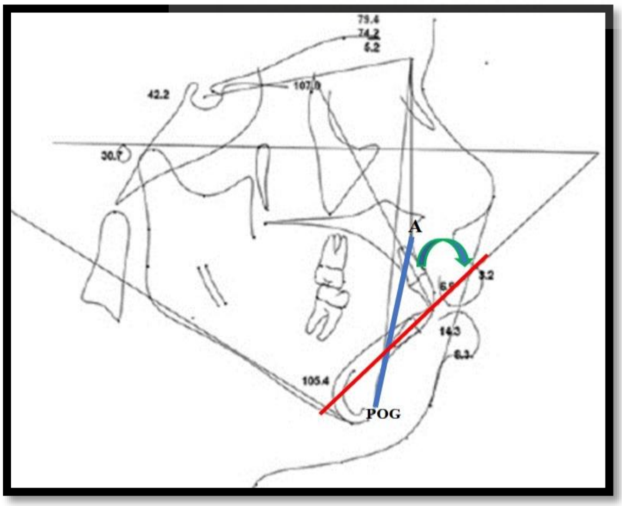

Figure 2: Cephalometric landmarks to identify incisor position

4.6 Data Collection

All the patients who met the inclusion criteria were selected from the archived records of a private practitioner (MC) in Cape Town, South Africa. The researcher used an MS Excel® spreadsheet to capture the descriptive details of the patient, including patient name, gender, date of birth, file number, malocclusion type, skeletal pattern and treatment protocol (extraction versus non-extraction). This ensured recording and capturing each patient's data only once.

On completion of the aforementioned process, the patients were further sub-divided into extraction and non-extraction treatment groups. Thereafter, each patient was assigned a numerical identity tknown only to the primary researcher, and kept in a separate sheet on his secure, private laptop. Descriptive details of the patients, which might possibly contribute to their identification, were not included in the sheet indicating the data. This blinded the researchers to the patients' descriptive and treatment details, but not to the specific points in time when the radiographs were captured.

4.7 Ethical Considerations

The Biomedical Research Ethics Committee (BMREC) of the Faculty of Dentistry at the University of the Western Cape approved the application to conduct this study (see Appendix A).

The study was of a retrospective nature, therefore none of the patients were exposed to any additional radiation. The cephalograms used in this study were taken during prior orthodontic treatment conducted by the private practitioner (MC).

Every patient who attended the practice of the private practitioner (MC) signed a consent form (see Appendix B), which included a section regarding consent for research purposes. This previously granted consent allowed the use of these patients' treatment records for the purpose of this thesis. Patient identity was not revealed during this stage as they had already been assigned a numerical number for the purpose of identification.

4.8 Statistical Analysis

All recorded data was entered in an MS Excel® spreadsheet. The researcher employed histograms and bar charts to demonstrate variables for continuous and categorical data respectively. For categorical data, a Chi square test was utilised. For continuous data, a repeated measures t-test or repeated measures ANOVA was used to demonstrate any differences. All data was significant at a p level of less than 0.05.

Inter- and intra-rater reliability were quantified by the intraclass coefficients (ICC) between the repeated measurements that had been taken. The ICC can vary between 0 and 1. An ICC of 0 indicates no reliability, whereas an ICC of 1 indicates perfect reliability (Weir, 2005) (see Table 3). Data analysis was carried out using SPSS (version 27). All statistical tests employed the 5% significance level.

Table 3: The interpretation of intraclass coefficients

ICC value	**Reliability**
<0.0	No reliability
0.0–0.5	Poor reliability
0.5–0.75	Moderate reliability
0.75–0.9	Good reliability
1.0	Perfect reliability

CHAPTER 5

RESULTS

5.1 Introduction

Descriptive data for the sample is presented in detail in tables 4 and 5. The final sample size comprised 82 patients, of whom 54 were females and 28 were males. Therefore females were overrepresented in the sample as they accounted for 65.9% (54/82) of the final sample. Furthermore, females comprised 44.44% of the extraction group (24/54) and 55.56% (30/54) of the non-extraction group. The males were 42.86% (12/28) in the extraction group and 57.14% (16/28) in the non-extraction group.

Table 4: Gender distribution demographics

Demographics according to gender		
Gender	**Frequency**	**Percentage %**
Females	54	65.9
Males	28	34.1
Total	82	100

Table 5: Gender distribution in extraction and non-extraction groups

Gender	Males		Females		Total n
	Frequency	%	Frequency	%	
Extraction	12	42.86	24	44.44	36
Non-extraction	16	57.14	30	55.56	46
Total	28	100	54	100	82

The overall mean age at the commencement of treatment for males in the extraction group was 13.3 years, while the mean age for males in the non-extraction group was 13.6 years. Similarly, the mean age at the commencement of treatment for females in the extraction group was 13.3 years, while the mean age for females in the non-extraction group was 13.7 years (see Table 6).

Table 6: Age distribution of extraction and non-extraction groups

Mean age at start of treatment (years) + standard deviation (SD)				**Mean age at end of treatment (years) + SD**			
Extraction		Non-extraction		Extraction		Non-extraction	
Males	Females	Males	Females	Males	Females	Males	Females
13.3 (2.0)	13.3 (1.8)	13.6 (1.2)	13.7 (1.3)	15.2 (1.3)	15.3 (1.5)	15.6 (0.8)	15.6 (1.2)

This study found that males underwent an average of 2.4 years of treatment in both the extraction and non-extraction groups. In addition the study determined that females exhibited a similar trend in treatment duration (see Table 7).

A linear regression was undertaken to determine if there were any statistically significant differences between patients' ages at the start of treatment, ages at the end of treatment and duration of treatment according to extraction and non-extraction cases and gender. There were no statistically significant differences between any of the above, p = 0.934, p = 0,909 and p = 0.620 respectively.

Table 7: Duration of treatment for extraction and non-extraction groups

Duration of treatment (years)		
Extraction	Males	2.4 (SD 0.6)
	Females	2.3 (SD 0.9)
Non-extraction	Males	2.4 (SD 0.7)
	Females	2.2 (SD 0.6)

5.2 Intra-examiner reliability for pre-treatment cephalometric measurements

The ICC quantified intra-examiner reliability for the pre-treatment mandibular incisor cephalometric measurements. The angular measurement L1–A-Pog exhibited moderate reliability, while the linear measure of L1–A-Pog (mm) and the IMPA showed moderate reliability. The FMIA had an ICC of 0.94, which indicated good reliability. Based on the ICC results, it was concluded that the pre-treatment cephalometric measurements were reliable.

Table 8: Intra-examiner reliability for pre-treatment cephalometric measurements

Pre-treatment	**ICC**	**95% Confidence interval**
L1–A-Pog (°)	0.56	0.11–0.88
L1–A-Pog (mm)	0.87	0.54–0.97
IMPA	0.83	0.42–0.96
FMIA	0.93	0.75–0.98

5.3 Intra-examiner reliability for post-treatment cephalometric measurements

The ICC quantified intra-examiner reliability for the post-treatment mandibular incisor cephalometric measurements. The angular measurement L1–A-Pog exhibited good reliability, while the linear measure of L1–A-Pog (mm), the IMPA and the FMIA showed moderate reliability. Based on the ICC results, the researcher concluded that the post-treatment cephalometric measurements exhibited moderate to good reliability.

Table 9: Intra-examiner reliability for post-treatment cephalometric measurements

Post-treatment	**ICC**	**95% Confidence interval**
L1–A-Pog (°)	0.83	0.42–0.96
L1–A-Pog (mm)	0.59	0.06–0.89
IMPA	0.63	0.01–0.90
FMIA	0.62	0.01–0.91

5.4 Inter-examiner reliability for pre-treatment cephalometric measurements

The ICC quantified the inter-examiner reliability for the pre-treatment mandibular incisor cephalometric measurements. The angular measurement L1–A-Pog exhibited moderate reliability, while the IMPA showed good reliability, and the linear measure L1–A-Pog (mm) as well as the FMIA displayed excellent reliability. Therefore the researcher concluded, based on the ICC results, that the pre-treatment cephalometric measurements exhibited moderate to excellent reliability.

Table 10: Inter-examiner reliability for pre-treatment cephalometric measurements

Pre-treatment	ICC	95% Confidence interval
L1–A-pog (°)	0.64	0.59–0 .91
L1–A-pog (mm)	0.90	0.59–0.97
IMPA	0.88	0.47–0.97
FMIA	0.98	0.94–0.99

5.5 Inter-examiner reliability for post-treatment cephalometric measurements

The ICC quantified the inter-examiner reliability for the post-treatment mandibular incisor cephalometric measurements. The linear measure of L1–A-pog (mm), exhibited moderate reliability, while the IMPA, the angular measurement of L1–A-Pog as well as the FMIA displayed good reliability. Based on the ICC results, it was concluded that the post-treatment cephalometric measurements exhibited moderate to good reliability.

Table 11: Inter-examiner reliability for post-treatment cephalometric measurements

Post-treatment	ICC	95% Confidence interval
L1–A-Pog (°)	0.84	0.30–0.96
L1–A-pog (mm)	0.54	-1.04–0.89
IMPA	0.82	0.20–0.95
FMIA	0.79	0.11–0.95

5.6 The absolute difference between the extraction and non-extractions cases for the mandibular incisor cephalometric values

The mean inclination angle (L1–A-Pog) and the mean IMPA increased post-treatment in both the extraction and non-extraction cases. However, the mean FMIA decreased post-treatment in both the extraction and non-extraction cases (see Figure 3 and Table 12).

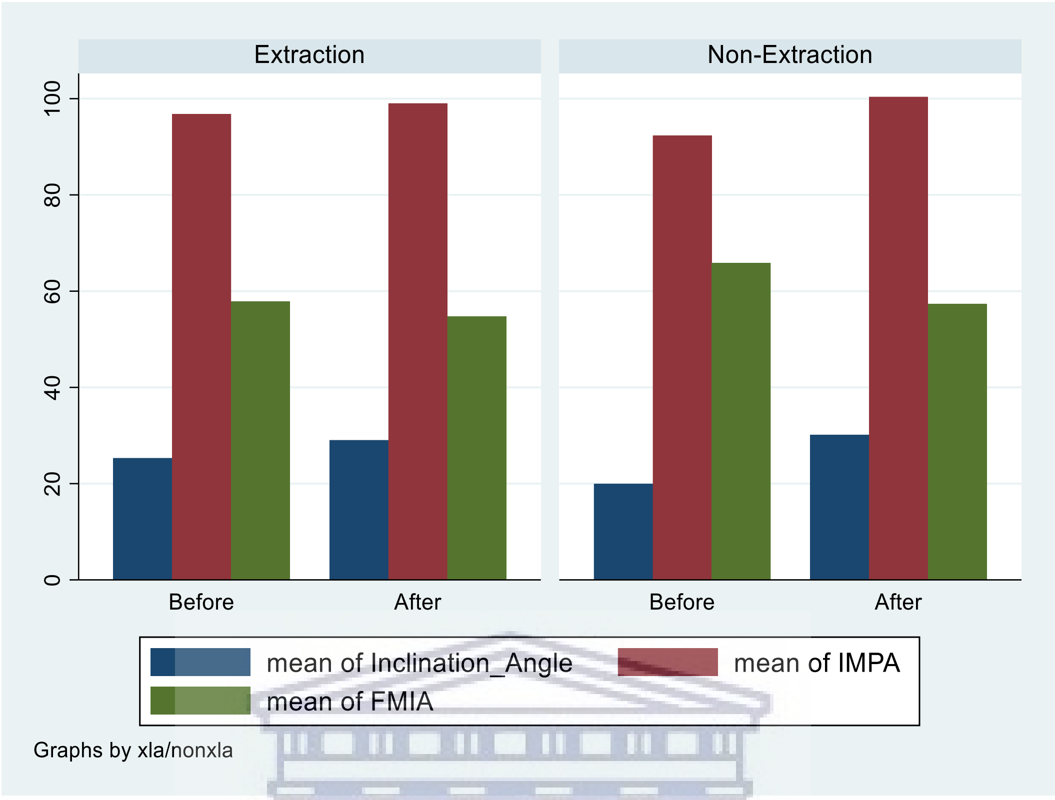

Figure 3: Pre- and post-treatment histogram of mandibular incisor inclination, IMPA and FMIA in extraction and non-extraction cases

Table 12: Pre- and post-treatment changes in extraction cases and non-extraction cases

L1–A-Pog (mean of inclination angle)	**Pre-treatment**	**Post-treatment**	**n**	**Difference (SD) After-Before**	**Confidence interval**	**P-value**
Extraction cases	25.32 (5.87)	29.05 (4.39)	36	3.73 (4.76)	2.12 to 5.34	0.0001*
Non-extraction cases	19.95 (3.94)	30.16 (4.29)	46	10.21 (5.06)	8.71 to 11.72	<0.0001*
	5,37 (3.21 to 7.53)*	**-1.10(-3.03 to 0.81)**				
IMPA						
Extraction cases	96.77 (7.07)	99.042 (6.89)	36	2.26 (3.77)	0.98 to 3.53	0.001*
Non-extraction cases	92.3 (5.12)	100.39 (5.63)	46	8.06*(5.07)	6.56 to 9.57	<0.0001*
	4.45 (1.76 to 7.14)*	**-1.34 (-4.1 to 1.4)**				
FMIA						
Extraction cases	57.86 (6.94)	54.74 (6.99)	36	-3.11 (4.44)	-4.62 to -1.62	0.0002*
Non-extraction cases	65.86 (6.31)	57.376 (5.94)	46	-8.48 (5.4)	-10.09 to -6.89	< 0.0001*
	-8.00 (-10.92 to -	**-2.63 (-5.48 to**				
Protrusion L1-A-Pog (mm)						
Extraction cases	1.99 (2.8)	2.39 (1.85)	36	0.4 (2.42)	-0.42 to 1.22	0.3295
Non-extraction cases	-0.75 (1.78)	2.25 (1.75)	46	3.00 (1.97)	2.42 to 3.59	<0.0001*
	2.74 (1.73 to 3.76)*	**0.14 (-0.65 to 0.93)**				

*Statistically significant

The values for the L1–A-Pog angle varied between 19.9°–30.1° from pre- to post-treatment in the non-extraction cases (see Table 11). The pre- to post-treatment values for the L1–A-Pog angle varied between 25.3°–29.0° in the extraction cases and from 19.95°–30.16° in the non-extraction cases. The L1–A-Pog displayed a smaller mean difference of 3.73° (SD 4.76) in the extraction group compared to the non-extraction group, where it exhibited a mean difference of 10.21° (SD 5.06) (see Table 11). The absolute difference between the extraction and non-extraction cases for the L1–A-Pog angle was 6.479 degrees, $p < 0.001$ (see Table 13).

Table 13: Mandibular incisor inclination difference between extraction and non-extraction cases

L1–A-Pog (°)	n	Mean (SD)	95% Confidence interval	P-value
Extraction cases	36	3.73 (4.76)	2.12–5.34	
Non-extraction cases	46	10.21 (5.06)	8.71–11.72	
Absolute difference		6.47 (SE = 1.09)		< 0.001

The IMPA ranged from 92.3° pre-treatment to 100.3° post-treatment in the non-extraction cases and from 96.7° pre-treatment to 99.0° post-treatment in the extraction cases (see Table 12) . In addition, the IMPA showed a smaller positive difference post-treatment in the extraction cases, namely 2.26 (3.77) degrees compared to the non-extraction cases, which was 8.06 (5.07) degrees, making this difference statistically significant (Table 12). The mean absolute difference between the extraction and non-extraction cases was 5.80 degrees, $p < 0.001$ (Table 14)

Table 14: Mandibular incisor inclination difference between extraction and non-extraction cases

IMPA	n	Mean (SD)	95% Confidence interval	P-value
Extraction cases	36	-2.26 (3.77)	-3.54–-0.99	
Non-extraction cases	46	-8.06*(5.07)	-9.57–-6.56	
Absolute difference		5.80 (SE = 1.01)		< 0.001

Pre-treatment values recorded for FMIA was 65.86° compared to 57.37° for post-treatment in the non-extraction cases. The FMIA values changed from 57.86° pre-treatment to 54.74° post-treatment in the extraction cases. There was a greater negative difference in the non-extraction cases, -8.48° (5.4) compared to the extraction cases, with -3.11° (4.44) for the FMIA readings (see Table 12). The absolute difference in the FMIA between the extraction and non-extraction cases was 5.36 degrees, p < 0.001 (see Table 15).

Table 15: Frankfort mandibular incisor angle difference between extraction and non-extraction cases

FMIA	n	Mean (SD)	95% Confence interval	P-value
Extraction cases	36	3.11 (4.44)	1.62 – 4.62	
Non-extraction cases	46	8.48 (5.4)	6.89 – 10.09	
Absolute difference		5.36 (SE = 1.11)		<0.001

With regard to L1–A-Pog (mm), the pre-treatment extraction group revealed a value of 1.99 mm compared to 2.39 mm for the post-treatment group (see Figure 4). The pre-treatment non-extraction group had a value of -0.75 mm compared to the 2.25 mm that was observed in the post-treatment non-extraction sample. There was a greater protrusion of 3.00 (1.97) mm in the non-extraction cases, compared to 0.4 (2.42) mm in the extraction cases. The mean absolute difference between the extraction and the non-extraction cases was 2.60 (SE 0.49), $p < 0.001$ (see Table 16).

Table 16: Difference in linear change in mandibular incisor between extraction and non-extraction cases

Protrusion (L1–A-Pog mm)	n	Mean (SD)	95% Confidence interval	p -value
Extraction cases	36	-0.4 (2.42)	-1.22 to 0.42	< 0.001
Non-extraction cases	46	-3.00 (1.97)	-3.59 to -2.42	
Absolute difference		2.60 (SE =0.49)		

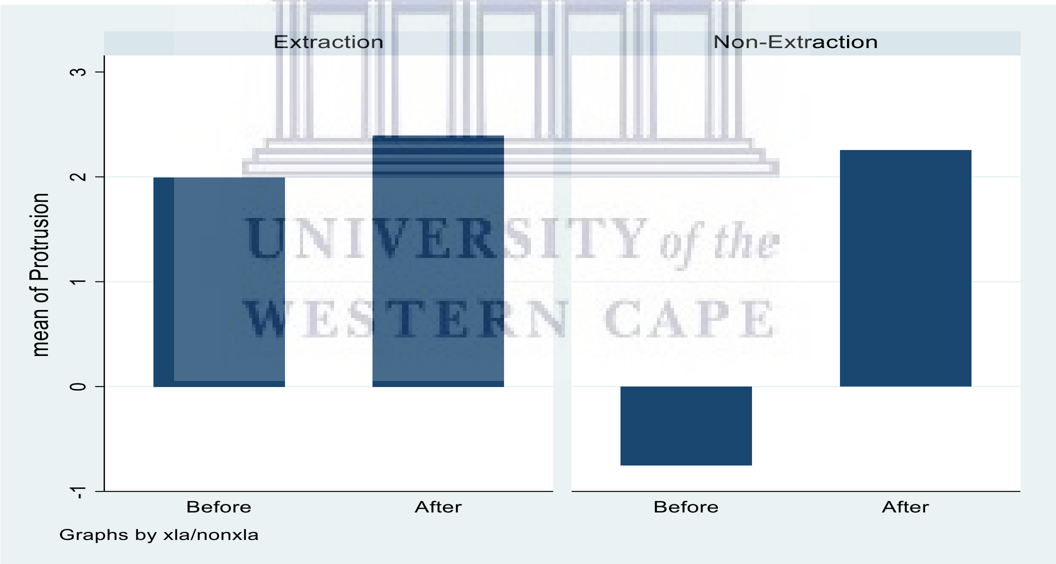

Figure 4: Protrusion of lower incisor to A-Pog plane

The largest absolute mean difference between the extraction and non-extraction groups was observed in the L1–A-Pog angle followed by the IMPA angle, the FMIA angle and the L1–A-Pog (mm). The L1–A-Pog (mm) exhibited the smallest absolute mean difference between the extraction and the non-extraction group.

CHAPTER 6

DISCUSSION

It is a common experience to find protrusion and proclination of the mandibular incisors during treatment of Class II malocclusions. In the absence of surgery and growth modification, as stated by Proffit and Ackerman (1994), the only remaining option would be to treat patients through dental compensation.

Successful Class II correction depends on a favourable response of the mandible to orthodontic forces. A Class II malocclusion that is treated by advancing all the mandibular teeth forward can result in poor facial aesthetics and compromised stability (Luppanapornlarp and Johnston, 1993).

The use of Class II inter-maxillary elastics is a treatment regime that most practitioners adhere to. This treatment approach produces undesirable side effects in the form of proclination of the mandibular incisors, protrusion of the mandibular incisors, extrusion of maxillary incisors, loss of mandibular anchorage, and the possibility of poor smile esthetics because of increased gingival exposure. In addition, Class II elastics result in the extrusion of mandibular molars as well as maxillary incisors, thereby creating a clockwise rotation of the occlusal plane. The latter also contributes to a downward and backward rotation of the mandible (Ellen, Schneider and Sellke, 1998). The private practitioner (MC) treated all the patients whose reports were used for this study using Class II (3.5 oz) elastics to allow for dento-alveolar correction of the overjet and molar relationship.

The sample size was based on the convenience sampling method. The researcher therefore obtained 82 patient records for the purpose of this study. However, the patients in the sample had undergone varying extraction protocols, namely group 4/4, group 5/5 or group 4/5. Steyn et al (1997) observe that less than 1 mm increase in retraction occurs between a 4/4 and a 5/5 extraction protocol. Furthermore, in the group with the 4/5 extraction protocol, greater incisor retraction, namely 2 mm, was observed. This is not clinically significant, hence, owing to the small sample size, the researcher did not differentiate between the different premolar extraction groups.

All the cases finished with the prescribed Damon® wire sequence and Class II elastics. It was observed that the lower incisors were proclined post-treatment. This finding concurs with the findings of previous studies (Nogueira et al, 2018; Vajaria, 2010). However, previous studies focused on the alleviation of crowding in non-extraction Class 1 cases while this study evaluated mandibular incisor proclination in Class II patients. The results of this study failed to demonstrate that the Damon® SLB system prevented lower incisor proclination with torque control. The incisor advancement seemed to be correlated with the loss of anchorage, raising further doubts about the lip bumper effect described by Damon (1998b).

The pre-treatment angles were larger for extraction cases compared to the non-extraction cases as regards L1–A-Pog and IMPA. The pre-treatment FMIA was smaller in the extraction cases compared to in the non-extraction cases. This is indicative of increased proclination in the pre-treatment extraction group when compared to the non-extraction sample, thereby highlighting the decision by the practitioner to extract teeth. The linear measurement of LI–A-Pog prior to treatment was larger in the extraction cases compared to the non-extraction cases. This yet again indicates why the decision was made to extract teeth within the arch. It is interesting to note that even though there is a statistically significant ($p = 0.0001$) difference between pre- and post-treatment angular values for L1–A-Pog, IMPA and FMIA, these values were not statistically significantly different from those recorded in the post-treatment phase.

The sample that underwent extractions showed a mean angular value of 29.0 (SD = 4.39) for L1–A-Pog while in non-extraction cases the mean post-treatment L1–A-Pog angular value was 30.16. The largest angular difference was for the FMIA, -2.632 (-5.48–0.212), followed by the IMPA, -1.34 (-4.1–1.4), and L1–A-Pog, -1.10(-3.03–0.81). All these confidence intervals included the null value of zero, which renders all these differences statistically not significant.

Greater proclination in the lower incisors was found in the non-extraction cases compared to the extraction cases when applying the L1–A-Pog angle. The mean angular difference of the L1–A-Pog in the non-extraction sample was 10.21 SD (5.06) ($p < 0.0001$). This is a significant finding as an association between the onset of recession and mandibular incisor proclination of greater than 10° have been reported (Pernet et al, 2019).

In the non-extraction cases, there was an increase in the 1MPA value between pre-treatment and post-treatment, thereby indicating an increase in the post-treatment inclination of the mandibular incisor. Similarly, the FMIA showed a slight reduction of the values post-treatment, when the values decreased from 65° pre-treatment to 57° post-treatment. This angle indicates that the mandibular incisors become more proclined to the FH post-treatment.

Damon (1998b) claimed that no proclination of the lower incisors occurred when using his bracket system. This study can refute the claim. However, it must also be acknowledged that mandibular incisor compensation is an accepted goal of treatment to camouflage the sagittal maxillo-mandibular relationship in skeletal Class II malocclusions.

Teeth respond to forces and moments and are not aware of the bracket type. A key issue is space. If space is available, the mandibular incisor teeth can be placed into a position of stability. This decision does not depend on appliance design or bracket type, but on the astute clinician taking into account the patient's facial profile, skeletal pattern and dentition (Vaden, Williams and Goforth, 2018).

CHAPTER 7

CONCLUSIONS

1. This study observed that both extraction and non-extraction treatment with the Damon® appliance system in skeletal Class II subjects exhibited protruded and proclined mandibular incisors.
2. Non-extraction cases overall showed a larger increase in mandibular incisor inclination (L1–A-Pog), linear measurement (L–A-Pog mm), IMPA and FMIA compared to extraction cases.
3. Orthodontic treatment that includes premolar extraction does not consistently cause a retrusive effect on the mandibular incisors. Proclination of the mandibular incisors may occur with any mandibular premolar extraction pattern.
4. The findings of this study contradict the lip bumper theory presented by Damon®. Mandibular incisor compensation is an accepted goal of treatment to camouflage the sagittal maxillo-mandibular relationship.

CHAPTER 8

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

There are several limitations to this study.

Firstly, all the subjects were derived from a single population group (a private dental practice). Patients were treated by one practitioner who applied the same archwire sequence, without using any other other appliance. This study design reduced potential selection bias, but it might have influenced the results and limited the generalizability of these findings to other population groups. Furthermore, this was a retrospective study without a control group, as there were no patients who had been treated with conventional 0.22 edgewise brackets or with active SLBs. The introduction of a control group could have shed light on the strengths and limitations of the Damon ® SLB system in Class II malocclusions.

The occlusal severity of the Class II malocclusion could have been described. This would have enabled characterisation of the sample by separating it into mild, moderate or severe Class II malocclusion, which would have had an impact on the treatment difficulty and final incisor position. The amount of crowding, Curve of Spee (CoS), arch length, intermolar and intercanine widths pre- and post-treatment were not recorded.

A deep CoS and mandibular incisor crowding requires space for levelling and alignment (Baldridge, 1969). Levelling the deep CoS or relieving mandibular incisor crowding can occur at the expense of lower incisor proclination. Pre-treatment crowding of greater than 5 mm has been shown to result in forward incisor movement (Shearn and Woods, 2000).

The effect of growth in the young patient must be given due consideration as there is an interaction between the mandibular incisor movement, sagittal and vertical movement of the chin as well as the effect of orthodontic treatment at point A. In hindsight, the effect of mandibular growth on final incisor position should have been recorded by using cephalometric superimpositions. These shortcomings are currently being addressed in a follow-up study.

Furthermore, the researcher found a lack of information about the periodontal phenotype prevailed. A strong correlation exists between a thin gingival biotype and orthodontic proclination (Joss-Vassalli et al, 2010). This factor was not an objective of the present study, although periodontal phenotype characterization is important as a thick, scalloped phenotype in the presence of good plaque control may allow for greater proclination of the mandibular incisors.

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APPENDICES

APPENDIX A: ETHICS CLEARANCE

UNIVERSITY *of the* WESTERN CAPE

60 YEARS *of hope, action & knowledge*

07 December 2020

Dr L Walton

Faculty of Dentistry

Ethics Reference Number: BM18/08/08

Project Title: Comparison of the proclination of mandibular incisors between Class II extraction and non-extraction cases using the Damon self-ligating system.

Approval Period: 17 April 2020 – 17 April 2023

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 annually by 30 November for the duration of the project.

Permission to conduct the study must be submitted to BMREC for record-keeping.

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

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University of the Western Cape
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Email: research-ethics@uwc.ac.za

NHREC Registration Number: BMREC-130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

APPENDIX B: PATIENT CONSENT FORM

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 Dr Marius Coetsee: ....

APPENDIX C: EXTRACTION CASES RAW DATA

No	Age Start of Rx	Age End of Rx	Duration of Rx (years, months)	Sex	Pre-Rx L1-Apo	Pre-Rx L1-Apog(mm)	IMPA	Pre-Rx Inclination (FMIA)	Post-Rx L1-Apog	Post-Rx L1-Apog	Post-Rx IMPA	Post-Rx FMIA
1	13	15	1,6	F	25,6°	1,5mm	95,0°	52,6°	25,6°	3,7mm	95,4°	46,4°
2	10	12	2	F	23,4°	2,9mm	90,2°	63,0°	20,8°	3,5mm	85,2°	71,1°
3	11	14	2,9	M	25,5°	2,9mm	93,7°	59,6°	29,4°	2,0mm	97,2°	54,9°
4	15	15	0,6	F	31,7°	3,3mm	107,8°	46,1°	34,4°	3mm	111,9°	41,1°
5	12	15	3,8	M	18,8°	-0,6mm	90,1°	58,5°	33,8°	5,2mm	97,3°	48,9°
6	15	17	2,1	F	27,1°	6,6mm	93,5°	48,5°	30,3°	4,5mm	99,7°	42,6°
7	13	15	1,8	F	24,7°	1,9mm	102,3°	59,9°	30,6°	0,3mm	100,7°	60,4°
8	12	14	2,3	F	13,3°	-1,0mm	84,5°	72,3°	25,5°	1,1mm	94,4°	59,5°
9	13	15	2,1	F	33,8°	4,2mm	98,2°	55,7°	29,8°	1,5mm	94,9°	60,0°
10	12	14	2,3	F	31,3°	4,8mm	103,9°	48,5°	34,5°	5,9mm	108,4°	44,1°
11	12	15	2,8	F	23,9°	2,3mm	91,9°	55,2°	25,7°	1,2mm	93,9°	53,1°
12	13	17	4,4	F	23,8°	0,8mm	97,6°	61,1°	28,3°	1mm	101,8°	58,4°
13	12	14	1,9	F	32,5°	4,5mm	99,6°	53,0°	33,0°	2,9mm	98,3°	54,1°
14	12	14	2,6	M	27,1°	5,3mm	97,2°	58,8°	28,3°	3,4mm	97,3°	57,6°
15	15	18	2,7	F	16,9°	-5mm	79,7°	71,7°	24,6°	0,1mm	84,0°	65,6°
16	13	15	2,5	M	33,3°	3,9mm	104,5°	57,4°	33,2°	1,6mm	101,7°	57,0°
17	15	17	2,2	F	30,8°	2,5mm	101,4°	59,0°	31,2°	0,6mm	99,2°	60,6°
18	12	13	1,11	F	29,5°	2,8mm	102,2°	51,7°	36,6°	3mm	107,0°	46,1°
19	14	16	2,3	F	28,7°	4,4mm	98,6°	50,6°	24,7°	3,1mm	94,0°	52,5°
20	13	16	2,7	M	22,1°	-1,8mm	94,0°	63,1°	25,2°	-0,1mm	93,1°	63,0°
21	11	14	2,9	F	20,0°	-0,7mm	94,4°	59,3°	23,3°	1,5mm	97,6°	56,8°
22	13	15	2,1	F	30,6°	1,9mm	108,9°	52,2°	30,3°	-0,1mm	106,6°	54,4°
23	12	15	2,4	M	29,5°	6,9mm	91,4°	51,3°	27,6°	6,4mm	92,5°	48,7°
24	12	16	3,9	F	29,0°	5,5mm	101,5°	52,9°	32,4°	4,3mm	104,1°	53,0°
25	13	15	2,2	M	28,2°	4,6mm	98,1°	59,1°	35,8°	3,7mm	106,1°	50,2°
26	13	16	2,9	F	27,7°	1,9mm	103,5°	50,0°	34,6°	0,6mm	106,0°	49,0°
27	13	15	2	M	25,8°	4,9mm	96,7°	63,2°	31,9°	4,9mm	104,4°	51,4°
28	15	16	1,2	M	31,4°	1,1mm	103,8°	56,5°	35,5°	1,5mm	107,0°	52,0°
29	12	14	1,7	F	19,0°	-0,1mm	88,5°	64,7°	22,1°	0,9mm	91,2°	57,9°
30	11	13	1,9	M	23,2°	1,7mm	98,7°	56,6°	24,1°	1,3mm	98,3°	57,2°
31	13	15	1,11	F	28,6°	0,4mm	108,4°	49,5°	31,1°	2,2mm	109,1°	47,8°
32	18			M								
33	17			F								
34	18			F								
35	13	15	2,4	F	24,6°	0,8mm	100,4°	60,2°	29,5°	2,2mm	103,9°	53,9°
36	14	16	2	F	23,7°	2,5mm	98,2°	54,5°	25,6°	3,8mm	103,0°	50,0°
37	14	16	2,1	M	23,3°	0,8mm	96,1°	63,6°	28,7°	3,0mm	99,1°	59,9°
38	12	17	4,3	F	8,2°	-4,7mm	88,4°	72,8°	27,4°	4,2mm	97,5°	63,7°
39	15	17	2,4	M	15,1°	-1,9mm	81,1°	70,4°	20,7°	-1,7mm	83,7°	67,9°

APPENDIX D: NON-EXTRACTION CASES RAW DATA

No	Age Start of Rx	Age End of Rx	Duration of Rx (years, months)	Sex	Pre-RxL1-APog	Pre-Rx L1-APog	Pre-Rx IMPA	Pre-Rx FMIA	Post-Rx L1-APog	Post-Rx L1-APog	Post-Rx IMPA	Post-Rx FMIA
1	13	15	2,1	M	21,2°	-0,5mm	95,3°	61,5°	31,7°	2,7mm	102,9°	54,3°
2	15	17	2,2	F	22,5°	-1,5mm	89,1°	62,8°	34,3°	2,5mm	93,6°	55,7°
3	14	16	1,9	F	15,4°	-2,4mm	85,1°	70,1°	32,9°	3,1mm	102,7°	51,4°
4	13	15	2,5	M	24,3°	0,3mm	95,2°	64,2°	35,6°	2,0mm	105,6°	51,8°
5	14	16	2,11	F	17,4°	0,4mm	86,4°	72,5°	27,3°	3,5mm	95,5°	57,7°
6	11	14	2,7	F	22,3°	-2,1mm	93,4°	64,5°	32,5°	-0,6mm	99,0°	61,5°
7	13	16	2,8	F	22,3°	-1,4mm	98,8°	66,1°	36,4°	1,4mm	112,1°	53,8°
8	12	16	3,2	F	19,6°	-0,8mm	101,8°	61,2°	30,4°	3,0mm	107,9°	52,9°
9	14	16	2,1	M	20,2°	0,1mm	98,3°	58,3°	29,4°	2,9mm	103,9°	51,4°
10	14	15	1,8	F	24,6°	1,5mm	97,5°	57,9°	37,0°	4,7mm	107,3°	46,3°
11	13	15	1,11	F	22,6°	-1,2mm	98,3°	61,6°	26,1°	-0,7mm	102,3°	59,7°
12	14	16	2,2	M	18,6°	0,4mm	91,4°	67,9°	28,3°	2,6mm	95,6°	62,5°
13	13	16	2,3	F	26,5°	3,3mm	94,9°	56,6°	35,3°	4,1mm	103,2°	50,8°
14	15	17	2	F	17,2°	-0,3mm	86,8°	74,9°	27,3°	1,1mm	98,4°	61,3°
15	15	17	2,2	F	17,2°	-0,9mm	88,6°	76,9°	26,1°	-0,7mm	97,8°	67,2°
16	14	17	3,5	M	20,3°	1,1mm	90,4°	63,9°	24,0°	2,7mm	95,1°	60,3°
17	15			F								
18	14	16	2	F	21,3°	-1,3mm	89,4°	67,4°	23,6°	0,4mm	91,1°	66,5°
19	15	17	2	F	18,9°	0,4mm	93,7°	63,7°	22,2°	1,9mm	97,1°	61,6°
20				F	28,2°	2,3mm	96,9°	60,7°	32,6°	3,0mm	101,6°	54,2°
21	15	16	1,3	M	22,9°	-0,6mm	93,1°	63,5°	32,9°	1,3mm	102,4°	55,6°
22	13	15	2,5	F	16,9°	-0,8mm	87,1°	60,4°	33,6°	7,7mm	95,5°	48,7°
23	13	16	3,2	F	18,4°	0,6mm	83,7°	63,4°	29,1°	2,9mm	91,3°	55,6°
24	13	15	1,6	M	25,0°	1,6mm	104,2°	57,5°	30,0°	3,5mm	105,2°	56,5°
25	13	17	4	M	27,4°	0,1mm	96,3°	59,6°	30,3°	1,5mm	95,2°	59,0°
26	13	15	2,8	F	20,5°	-2,1mm	92,9°	68,0°	28,9°	1,9mm	96,5°	65,4°
27	17			F	23,0°	1,1mm	91,1°	61,0°				
28	14			M								
29	13	15	2,6	F	22,5°	-1,1mm	95,2°	66,0°	29,2°	2,0mm	101,1°	57,7°
30	13	16	3,2	F	12,4°	-5,5mm	92,4°	69,6°	34,0°	3,3mm	112,8°	50,3°
31	14	16	1,9	F	25,3°	-1,5mm	92,5°	74,3°	34,0°	-1,7mm	102,8°	60,1°
32	14	16	1,8	F	13,3°	-2,3mm	85,5°	73,1°	28,7°	1,8mm	97,7°	59,9°
33	14	16	2,4	F	23,4°	3,5mm	90,8°	62,5°	27,8°	5,9mm	95,0°	59,2°
34	14	16	2	M	17,6°	-3,7mm	87,6°	70,5°	37,2°	2,9mm	107,1°	52,1°
35	14	16	1,8	M	13,0°	-3,6mm	82,9°	84,8°	30,0°	0,4mm	96,8°	70,6°
36	15	17	2,6	F	15,9°	-2,1mm	96,3°	61,1°	33,7°	4,1mm	107,0°	48,5°
37	12	14	1,8	F	14,9°	-2,5mm	85,7°	70,9°	20,1°	1,2mm	90,9°	67,7°
38	13	15	2,3	M	21,6°	-0,1mm	97,5°	60,3°	27,6°	1,4mm	99,2°	57,3°
39	11	13	1,7	F	23,9°	1,1mm	95,6°	56,1°	31,1°	4,1mm	98,0°	52,9°

40	14	16	1,11	F	22,4°	-0,4mm	94,2°	69,3°	39,9°	0,5mm	111,0°	50,3°
41	13	16	3,2	M	16,4°	-2,7mm	87,9°	73,9°	25,8°	0,8mm	94,9°	70,2°
42	12	13	1,7	F	18,2°	-0,5mm	88,8°	67,0°	28,6°	2,8mm	99,2°	55,8°
43	12	14	1,11	F	20,9°	-0,4mm	97,2°	60,5°	23,0°	2,0mm	96,8°	60,9°
44	18			M								
45	14	16	2,1	F	18,4°	-1,8mm	93,5°	72,2°	26,2°	0,6mm	100,7°	63,4°
46	13	15	2,9	M	21,2°	-0,8mm	94,9°	64,8°	29,1°	2,7mm	102,1°	56,6°
47	12	14	2,1	M	14,9°	-1,5mm	81,9°	74,1°	30,1°	4,3mm	95,0°	59,2°
48	16			F								
49	15			F								
50	13	15	2,5	M	15,3°	-2,1mm	88,0°	67,8°	26,7°	0,6mm	95,6°	59,8°
51	14	16	2,1	F	20,5°	0,7mm	99,3°	55,6°	32,5°	3,4mm	107,5°	47,8°
52	13	15	2,6	M	14,1°	-3,4mm	90,7°	70,3°	34,5°	2,2mm	108,0°	57,3°

APPENDIX E1: RAW DATA FOR ESTABLISHING INTRA-EXAMINER RELIABILITY (T1)

T1: time of initial data capture

No	Sex	Pre-Rx L1-APog	Pre-Rx L1-APog(mm)	Pre-Rx IMPA	Pre-Rx FMIA	Post-Rx L1-APog	Post-Rx L1-APog	Post-Rx IMPA	Post-Rx FMIA
1	F	23,2°	1,3mm	92,9°	53,5°	23,1°	2,9mm	93,6°	51,9°
11	F	23,0°	1,9mm	92,9°	55,7°	25,4°	1,1mm	93,0°	55,2°
21	F	21,7°	0,7mm	94,9°	59,6°	26,9°	1,5mm	99,5°	53,4°
31	F	27,1°	0,6mm	106,8°	52,1°	29,8°	2,4mm	106,3°	50,2°
1	M	21,2°	-0,2mm	95,6°	63,1°	31,7°	2,2mm	103,4°	54,1°
11	F	22,2°	-1,8mm	98,5°	60,7°	28,7°	-0,1mm	104,7°	56,9°
21	F	16,8°	-0,1mm	86,3°	59,9°	27,5°	5,3mm	93,8°	49,6°
31	M	15,2°	-3,7mm	84,5°	74,6°	38,6°	2,0mm	106,6°	50,2°
41	F	17,3°	-2,4mm	92,7°	71,9°	23,8°	0,1mm	100,0°	64,3°

APPENDIX E2: RAW DATA FOR ESTABLISHING INTRA-EXAMINER RELIABILITY (T2)

T2: day 14 of data capture

No	Sex	Pre-Rx L1-Apog	Pre-Rx L1-Apog(mm)	Pre-Rx IMPA	Pre-Rx FMIA	Post-Rx L1-APog	Post-Rx L1-Apog	Post-Rx IMPA	Post-Rx FMIA
1	F	22,3°	0,7mm	92,4°	53,5°	24,9°	3,5mm	94,5°	50,8°
11	F	22,9°	2,4mm	90,1°	57,3°	26,0°	1,4mm	93,8°	55,8°
21	F	17,4°	-1,0mm	93,1°	63,3°	25,0°	1,3mm	99,3°	55,3°
31	F	24,4°	-0,7mm	107,2°	51,3°	28,8°	2,4mm	105,7°	51,1°
1	M	19,4°	-1,4mm	97,1°	65,1°	30,5°	2,4mm	101,9°	56,2°
11	F	21,0°	-1,6mm	98,0°	62,5°	27,3°	-0,2mm	102,3°	59,6°
21	F	14,4°	-1,2mm	86,4°	59,0°	27,4°	5,3mm	93,8°	49,4°
31	M	15,3°	-3,4mm	86,3°	73,4°	36,2°	1,9mm	106,0°	53,1°
41	F	16,2°	-2,5mm	92,6°	71,8°	27,7°	0,4mm	102,6°	61,4°

APPENDIX F: RAW DATA FOR ESTABLISHING INTER-EXAMINER RELIABILITY

No	Sex	Pre-Rx L1-APog	Pre-Rx L1-APog(mm)	Pre-Rx IMP	Pre-Rx FMIA	Post-Rx L1-APog	Post-Rx L1-APog(mm)	Post-Rx IMPA	Post-Rx FMIA
1	F	23,2°	1,3mm	92,9°	53,5°	23,1°	2,9mm	93,6°	51,9°
11	F	23,0°	1,9mm	92,9°	55,7°	25,4°	1,1mm	93,0°	55,2°
21	F	21,7°	0,7mm	94,9°	59,6°	26,9°	1,5mm	99,5°	53,4°
31	F	27,1°	0,6mm	106,8°	52,1°	29,8°	2,4mm	106,3°	50,2°
1	M	21,2°	-0,2mm	95,6°	63,1°	31,7°	2,2mm	103,4°	54,1°
11	F	22,2°	-1,8mm	98,5°	60,7°	28,7°	-0,1mm	104,7°	56,9°
21	F	16,8°	-0,1mm	86,3°	59,9°	27,5°	5,3mm	93,8°	49,6°
31	M	15,2°	-3,7mm	84,5°	74,6°	38,6°	2,0mm	106,6°	50,2°
41	F	17,3°	-2,4mm	92,7°	71,9°	23,8°	0,1mm	100,0°	64,3°

APPENDIX G:TURN-IT-IN REPORT

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11 December 2020

Dear Sir/Madam

RE: TURN-IT-IN REPORT FOR DR LW WALTON

I hope this document finds you well.

The turn-it-in report for Dr Walton's mini-thesis had a score of 30%. The analysis revealed that 13% was as a result of a previous submission to the University of the Western Cape.

As part of the Research Module in 2018, Dr Walton had to submit a literature review on Turn-it-in. The submission of 2018 accounts for the 13% in the current score on Turn-it-in for the mini-thesis submission. Without the previous submission for work already done by Dr Walton, the final score for the Turn-it-in report for the mini-thesis would result in 17%.

I hope you will find this in order.

Kind regards

L. Walton

TURN-IT-IN REPORT (LIT REVIEW 2018)

TURN-IT-IN REPORT (MINITHESIS 2020)


MiniThesis

ORIGINALITY REPORT

%30	%9	%18	%16
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to University of the Western Cape Student Paper	%13
2	Michael J. Riger. "Use of an incisor diagnostic triangle for evaluating incisor positions relative to the APo line", American Journal of Orthodontics, 1979 Publication	%1
3	Al-Nimri, K.S.. "Changes in mandibular incisor position in Class II Division 1 malocclusion treated with premolar extractions", American Journal of Orthodontics & Dentofacial Orthopedics, 200312 Publication	%1
4	Brittany N. Shearn, Michael G. Woods. "An occlusal and cephalometric analysis of lower first and second premolar extraction effects", American Journal of Orthodontics and Dentofacial Orthopedics, 2000 Publication	%1
5	"ABSTRACTS OF LECTURES AND POSTERS	