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MEASURING THE PREDICTABILITY OF TARGET SET-UP IN CUSTOMIZED LINGUAL ORTHODONTIC TREATMENT

DOCTOR OF PHILOSOPHY THESIS

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated .... and numbered ....

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

Date

Pelin BABAYİĞİT

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LIST OF SYMBOLS AND ABBREVIATIONS

ARS	Air Rotor Stripping
B-Tİ	Beta Titanium
BEST	Bonding with Equal Spesific Thickness System
CAD/CAM	Computer Aided Design-Computer Aided Manufacturing
CBCT	Cone Beam Computed Tomography
CCLA	Completely Customized Lingual Appliance
CLASS	The Custom Lingual Appliance Setup Service
CO-Cr	Cobalt-Chrome
DALI	Dessin de l'Arch Linguale Informatise
IPR	Interproximal Reduction
KIS	Korean Indirect Bonding Set-up System
LBJ	Lingual Bracket Jig
SE NİTİ	Super Elastic Nickel Titanum
SS	Stainless Steel
STb	Scuzzo Takemoto Braces
TARG	Torque Angulation Reference Guide
TMA	Titanium Molybdenum Alloy
TOP	Transfer Optimized Positioning

ABSTRACT

Babayiğit, P. (2024). Measuring the Predictability of Target Set-up in Customized Lingual Orthodontic Treatment. Yeditepe University, Institute of Health Sciences, Department of Orthodontics, PhD Thesis, İstanbul.

This study was conducted to evaluate the accuracy of planned tooth movements in patients who were treated with completely customized lingual orthodontic system. In our study to assess the tip, torque, rotation, mesiodistal translation, buccolingual translation and vertical translation, three dimensional digital models were superimpositioned. The discrepancy between set-up and treatment result was measured in GeoMagic Control X program. In evaluating the findings of the study, IBM SPSS Statistics 22 software was employed for statistical analyzes. Total of 624 teeth were measured in both jaws. Buccolingual translational measurements were greater at the upper jaw (p: 0.046). For the rotation, tip, torque, buccolingual translation and mesiodistal translation discrepancy, posterior teeth were greater than anterior teeth with a statistically significant difference. For the upper and lower jaw, all teeth were positioned more retrusive except tooth number 16 in torque measurements. Vertical discrepancy measurements were statistically significant in tooth number 33 (p:0.034). Upper central incisors were positioned more extruded according to the set-up, lateral incisors were intruded,canines, premolars and molars were extruded. For the lower jaw, opposite results were obtained for every tooth group. For the buccolingual discrepancy measurements, teeth number 41 and 42 were positioned more buccally with a statistically significant difference (p:0.004, p:0.002). But tooth number 43 was positioned more lingually with p:0.023. Upper central incisors were positioned more buccally, all other teeth were positioned more lingually. In conclusion, the discrepancy difference was considerably low with all the measurements. Completely customized lingual orthodontic system is definitely a great choice for orthodontists and give accountable predictions in all tooth movements.

Key words: Completely Customized , Lingual Brackets, Tooth Movements, Treatment Accuracy

TÜRKÇE ÖZET

Babayiğit, P. (2024). Kişiye Özel Lingual Braket Sistemlerinde Planlama Öngörülebilirliğinin Değerlendirilmesi. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Ortodonti ABD., Doktora Tezi. İstanbul.

Bu çalışma, tamamen kişiye özel üretilmiş lingual ortodontik sistemle tedavi edilen hastalarda planlanan diş hareketlerinin doğruluğunu değerlendirmek amacıyla gerçekleştirilmiştir. Tip, tork, rotasyon, meziodistal translasyon, bukkolingual translasyon ve vertikal translasyonu değerlendirmek için üç boyutlu dijital modeller çakıştırılmıştır. Set-up ve tedavi sonucu arasındaki fark, GeoMagic Control X programında ölçülmüştür. Çalışmanın bulgularını değerlendirirken, istatistiksel analizler için IBM SPSS Statistics 22 yazılımı kullanılmıştır. Her iki çenede toplamda 624 diş ölçülmüştür. Bukkolingual translasyon ölçümleri üst çenede daha büyük bulunmuştur (p: 0.046). Rotasyon, tip, tork, bukkolingual translasyon ve meziodistal translasyon farkı değerlendirildiğinde, arka grup dişler ön grup dişlerden istatistiksel olarak anlamlı bir farkla daha büyük bulunmuştur. Üst ve alt çenede, tüm dişler set-up'a göre daha negatif torklu konumlanmıştır, sadece 16 numaralı diş tork ölçümlerinde daha labialde konumlanmıştır. Vertikal fark ölçümleri sadece 33 numaralı dişte istatistiksel olarak anlamlı bulunmuştur (p:0.034). Üst santral kesici dişler daha labialde konumlanmış, yan kesici dişler daha lingualde, kanin dişleri, premolarlar ve molarlar daha labialde konumlanmış bulunmuştur. Alt çenede, her diş grubu için tam ters sonuçlar elde edilmiştir. Bukkolingual uyumsuzluk ölçümleri için, 41 ve 42 numaralı dişler istatistiksel olarak anlamlı bir farkla daha bukkalde konumlanmıştır (p:0.004, p:0.002). Ancak 43 numaralı diş, p:0.023 ile daha lingualde bulunmuştur. Üst santral kesici dişler daha bukkalde konumlanmış, diğer tüm dişler daha lingualde ölçülmüştür. Sonuç olarak, tüm ölçümlerde fark oldukça düşük bulunmuştur. Tamamen kişiye özel üretilmiş lingual ortodontik sistemlerin, ortodontistler için oldukça başarılı bir seçenek olduğu kanısına ulaşılmıştır ve tüm diş hareketlerinde öngörülebilir tahminler sunduğu görülmüştür.

Anahtar Kelimeler: Diş Hareketi, Doğruluk, Kişiye Özel Üretim Braketler, Lingual Braketler

1. INTRODUCTION

Today , the aligning of the anterior teeth and their appearance is an outstanding factor for general dentistry area and also for the patients. Patients request a better physical appearance as well as a better function and occlusion. The physical appearance which constitutes the esthetic of the patient effects the social life, business life and also the personality itself.(1)

Aiming to provide the patients' needs, orthodontic community invented different types of appliances appearing more 'invisible', meaning more esthetic. From ceramic brackets to clear aligners and lingual brackets, patients now have a wider range of options that offer both functional and esthetic benefits. As a result, orthodontic treatment has become more accessible and acceptable for many patients.

Lingual orthodontic treatment is applied from the lingual side of the teeth leading a more discrete orthodontic treatment contrarily to labial treatment. This factor leads the patients to choose lingual orthodontic treatment method. The long duration of orthodontic treatment pushes the orthodontists to try new appliances to conduct the treatment in a more esthetic way.

Early in time, lingual orthodontic method was found to be hard to apply and complicated for many orthodontists for a long time, but it is getting more popular day after day because of patients' requests. In time, this request has directed the orthodontics world to enhance the appliance system, to speed up the treatment time and to succeed the same results with the labial appliances.

Lately, the percentage of patients choosing lingual treatment increases, new lingual appliance techniques emerge and these techniques ease the treatment process. Accordingly, the results are as successful as the conventional treatment meaning the development and usage of lingual technique will win a seat inevitable in orthodontics world.

In this study, the purpose is to analyze the treatment outcome of completely customized lingual orthodontic treatment by digitally superimpositioning the treatment set-up and the treatment result.

2. GENERAL INFORMATION

2.1. History of Lingual Orthodontics

Lingual orthodontics is an esthetic alternative to traditional labial orthodontics when the patient is seeking orthodontic treatment. Past times, orthodontic treatment was applied mostly on younger patients and adolescents but today it is conducted on adults too. Especially in 1970's, orthodontic treatment on adults has increased and continued to gain acceleration in 1990's. (2) Most part of adult patients deny the conventional fixed orthodontic treatment because of social and vocational concerns.(3) Accordingly, the need for 'invisible' treatment is increased and the term 'lingual' has come out.

The increasing demand for adult treatment brought unique concerns for orthodontics world. To address this demand, plastic and ceramic brackets, teflon arch wires are produced by manufacturers.(4) But with the staining problems this wasn't a pleasing solution.(4) Nevertheless, the search continued for the esthetic solution.

Lingual orthodontic treatment has been applied for many years but hasn't received the desired attention because of its disadvantages from former designs, such as patient adaptation, bracket failure rates, rebonding difficulties and finishing stage challenges. Also, biomechanical differences from labial orthodontics made it less popular for some orthodontists.

First ever mentioned lingual orthodontics is by Pierre Fauchard in 1726.(5) Later in 1800s Pierre Joachim Lefoulon described lingual appliance design for expansion of the arches and aligning of teeth.(6) After the era of Edward Angle, the creator of modern orthodontics, orthodontists combined labial orthodontics with lingual appliances such as lingual arch, transpalatal bar and quadhelix.(7,8)

Early 1970's, Dr.Craven Kurz ,who was an orthodontist and assistant professor at UCLA School of Dentistry, observed that the number of adult patients were increasing significantly at his private clinic. Many of his patients were public figures and celebrities so the esthetic appearance was a major concern for most of them. One day, an employee of Playboy Bunny Club presented him with orthodontic treatment request. She particularly wanted an invisible treatment so Dr.Kurz created the first ever lingually bonded appliance.(9)

He consulted with his colleagues often and developed the first true lingual appliance. He bonded the plastic brackets with Dr.Jim Mulick at the lingual side of anterior dentition and metal brackets at the lingual aspect of posterior dentition. Plastic brackets were the choice of selection because the ease of recontouring if in direct contact with opposing dentition. He observed every stage to upgrade the system if in need. In time he found that occlusal forces cause shearing forces on the maxillary brackets and bring bond failures often. Moreover, it was disturbing for patient's tongue. So, in mid 1970's, he smoothened the bracket surface with stones which led to increasing comfort of patients.(9)

These developing news and commercial interests bring the manufacturer Ormco (Ormco Corporation, Glendora, CA, USA) to create a product development team to work with Dr.Kurz. Many new prototypes were developed to improve the original appliance. The main problem was the shearing forces which led to bracket failure so eventually they designed an anterior inclined plane as an integral part of the maxillary anterior brackets so that it can convert the shearing forces to compressive forces which were applied by mandibular incisors.(9)

With this encouraging and promising development, Dr.Kurz applied for the patent of Kurz lingual appliance in 1976. Afterwars in 1979, Ormco manufatured a usable metal bracket. The clinical testing was held in Dr.Kurz's private clinic on 100 patients over 3 years. These tests showed that this appliance is promising and viable. So, the next step was to constitute beta test sites for product improvement. Ormco sponsored 50 selected orthodontists to attend a lingual orthodontic therapy symposium presented by Dr.Kurz with finalized 100 cases. This task force tested and learned the appliance all over and gather experience.(9)

The exciting news of an esthetic alternative to traditional labial brackets were spreading internationally. In 1979, Dr.Kinya Fujita from Japan made a significant development. He used a mushroom shaped arch wire and used multi-bracket system lingually.(10) He had first started his studies in 1971 and published his first literature about the case he conducted with first premolar extractions.(10) 1981, Dr.K.Fujita of Japan published an article on lingual therapy at American Journal of Orthodontics. Many manufacturers and companies wanted to be ahead of this new trending system to compete. The task force was giving conferences in major cities of America. Ormco decided to have task forces of 2 orthodontists at every country in Europe. Courses were given in Geneva, Switzerland and followed by Japan. Thousands of orthodontists attended these courses and started to have their own cases. In 1986 French Orthodontic Society founded the French Orthodontic Society of Lingual Orthodontics.(10) Also in 1986, Prof.Dr.Mustafa Ülgen applied lingual technique on his patient and published a literature about this for the first time in Turkey.(11)

In 1987, American Association of Orthodontists meeting was held in Montreal, Canada. Dr.Kurz was also in the program to discuss the problems in lingual orthodontic therapy. Mostly the problems consisted of bracket placement which was direct placement and manipulation of arch wires.(9)

At this same meeting, a new alternative esthetic solution was presented to orthodontists. A clear, stain-resistant labial bracket was introduced called Starfire. The clinicians lost their interests day by day praising this new labial bracket since it was more esthetic contrarily to metal brackets but easier contrarily to lingual brackets.(9)

In 1987 American Lingual Orthodontics Association was established. Task forces were giving more private and hands-on courses to support clinicians. In 1992 European Society of Lingual Orthodontics was founded. Asian lingual association was also active. Many courses are given around the world mainly by Dr.Didier Fillion from France, Dr.Guiseppe Scuzzo from Italy, Dr.Courtney Gorman from USA, Dr.Kyoto Takemoto from Japan, Dr.John Napolitano and Dr.Mario Paz from USA.(9) Hereby, this technique was spread all around the world with circulation up till today.

2.2. Development and Improvement of the Lingual Treatment

Lingual orthodontic system was upgraded and evolved by many orthodontists as time progressed but still it wasn't as easy as the labial technique for many doctors. Main problems and concerns were listed as (9)

-Tissue irritation and speech difficulties

-Gingival impingement

-Occlusal interference

-Base pad adaptation

-Appliance placement and bonding

-Wire placement, ligation and attachments

Accordingly, lingual bracket design evolved immensely in time. From 1976 to present; occlusal bite planes, hooks, inclined planes, transpalatal bars and caps were added and modified to improve the function and comfort. (12–14)

In 1994, Massimo Ronchin from Italy, created a self-ligating lingual bracket applied with Begg technique. Same company produced a bracket system with no torque control but good at aligning simple anterior crowding cases. (15)

Dr.Scuzzo and Dr. Takemoto created together the Scuzzo/Takemoto (Stb) bracket system which is applied with straight-wire technique. It increased to patient comfort but also decreased the friction force.(16)

In 2002, today's one of the most advanced lingual appliance system was created by Dr.Dirk Wiechmann from Germany, and in 2009 the 3M company took over the brand Incognito (3M Unitek,USA). Later on he released another system WIN (DW Lingual Systems, Germany). Both these systems are completely customized, both brackets and arch wires, for patient. (17) The bracket base is designed with CAD/CAM according to lingual side of every tooth with 3D scanners and manufacturing. The angles of the bracket slot are defined according to the need of tipping and torque of that specific tooth. Following the bracket design, the arch wire sequences are bent with a special robotic system according to the orthodontist's treatment plan. Many similar examples of this system are manufactured with different brand names. All of these laboratory procedures and applications will be explained later in this thesis.

2.3.Biomechanics in Lingual Orthodontics

Biomechanics in orthodontics refers to study of the mechanical forces applied to the teeth and the surrounding tissues during orthodontic treatment. This involves understanding the anatomy of the teeth, the behavior of orthodontic materials, and the response of the surrounding tissues to these forces. In lingual orthodontics, the mechanics involved in treatment can be different from those in traditional orthodontics due to the placement of the brackets on the lingual surface of the teeth.

Understanding the biomechanics and application of force in orthodontic treatment improves the efficacy of treatment and simplifies the technique. Force delivery is also improved and the side effects are decreased with better perception.

Fish introduced the idea of center of resistance to the field of dentistry in 1917, which was initially a concept in mechanics focused on rigid bodies.(18) He analyzed a single rooted tooth and concluded that when a tooth is subjected to a horizontal force, it will experience a bodily movement if the force is applied through a specific point located somewhere between the apex and the alveolar crest. This point may be called the center of resistance. It is analogous to the concept of the center of mass of a free body.

The center of resistance is the point where the force vector causing the tooth's translation movement intersects the long axis of the tooth. It is a fundamental reference point for controlled tooth movement. Forces produce either translation, rotation, or a combination of translation and rotation, depending upon the relationship of the line of action of the force to the center of resistance of the tooth.(19) The rotation center is an imaginary point around which tooth moves due to the applied forces. Its location changes according to the forces applied to the tooth. If a force is applied from the bracket plane to a single-rooted tooth , a rotation center will occur a little apically, and the tooth will rotate around this point. When forces causing translation movement are applied, the rotation center is located at infinity. (19)

The line of effect of forces that do not pass through the resistance center of the tooth creates a rotational effect around the tooth's rotation center. This effect is called the moment of force. Moment is the product of the intensity of the force and the vertical distance from the force's line of effect to the resistance center of the tooth.(19)

The resistance center of single-rooted teeth is located 24-35% of the distance from the alveolar crest to the tooth root along the axis of the tooth. The resistance center of upper molars is located closer to the palatal region in the horizontal plane and approximately in the center of the trifurcation in the vertical plane. The resistance center of lower molar teeth is located in the center of bifurcation in both vertical and horizontal planes. (19) The resistance center may vary depending on the morphology of the tooth, quality of the alveolar bone, and inclination of the tooth.

The primary distinction between labial and lingual techniques originates from the difference in the rotation center of teeth and the point where force is applied. In lingual orthodontic treatment, the forces applied are closer to the resistance center of teeth, leading to a reduction in tipping and an increase in parallel movement during tooth displacements(20).

The use of force on both labial and lingual brackets has been analyzed for its impact by Scuzzo and Takemoto, revealing various biomechanical differences between lingual and labial orthodontic treatment techniques. In lingual orthodontics, the point where force is applied is proximate to the tooth's axis. These anatomical considerations require substantial biomechanical evaluations. Achieving an effective force couple during rotational movements on the lingual surface poses challenges. The rotational moment in the lingual direction is comparatively diminished. Placing arch wires on lingual brackets for cases involving malocclusion is more intricate than in labial placement, necessitating the use of more flexible wires. (21)

Lingual orthodontic treatment introduces biomechanical distinctions arising from the point where force is applied in relation to the tooth's center of resistance. While the closure effect in lingual orthodontics varies depending on the bracket systems in use, it generally tends to induce closure. Upper brackets act similarly to a bite plane, establishing contact with the incisal edges of lower incisors, resulting in incisor intrusion and molar extrusion. The use of low-profile brackets ,for example STb system, diminishes this effect. This system contributes to a reduction in the axial inclination of maxillary incisors, but achieving effective torque control remains challenging, presenting one of the complexities of lingual orthodontics. Unregulated moments and forces may lead to a higher incidence of root resorption compared to the labial technique(22).

In lingual orthodontics, the point of force application is close to the axis of the tooth. These anatomical factors necessitate crucial biomechanical evaluations. It is challenging to achieve an effective torque force on the lingual surface during rotational movements. The rotational moment in the lingual direction is less than that in the labial direction. Placing arch wires in lingual brackets in cases of malocclusion is more challenging than in labial placements, hence the need for more flexible wires. (21)

During lingual orthodontic treatment, the anteroposterior changes observed involve the mandible undergoing downward and backward rotation with the opening of the bite, potentially leading to the development of a Class II inclination. However, correcting the anteroposterior molar relationship may become easier with the opening of the bite.(23)

In the sagittal plane, when equal amounts of intrusion and retraction force are applied to the incisors, the force vector in the labial system passes through the resistance center of the tooth, whereas in the lingual system, it passes more lingually to the resistance center. This results in lingual tipping and vertical bowing movement in the incisors. Therefore, during en masse retraction, the retraction force should be minimized for retracting the incisors, and the forces for intrusion and torque should be increased.(21)

Another difference is the contact point between the teeth. In the molar region, the contact points between the teeth are closer to the buccal side. The wide interproximal space on the lingual side, when retraction forces are applied, leads to more crown rotation from lingual forces compared to labial forces.(21)

Molar distalization can be achieved more easily with lingual orthodontic treatment. The ease of this movement is attributed to the forces applied in lingual technique being closer to the resistance center of the tooth, resulting in less distal tipping and more parallel movement.(9)

The first and most noticeable vertical change observed is the opening of the bite due to contact between the lower incisors and the upper incisor brackets in the biting plane. This situation becomes advantageous in brachycephalic cases, certain temporomandibular joint disorders, or situations where faster tooth movement is desired, often leading to the formation of posterior gaps.(23)

The resistance center in a maxillary molar is positioned closer to the trifurcation area in the vertical plane and more lingually in the horizontal plane. In a mandibular molar, the resistance center is located near the bifurcation area in the vertical plane and centrally in the buccolingual direction in the horizontal plane. Unlike labial brackets in the vertical plane, lingual brackets on maxillary incisors are positioned closer to the long axis of the resistance center. Therefore, applying an occlusal force results in easier tooth movement. However, in lingual technique, the shorter distance between brackets compared to conventional labial brackets is noted to bring the resistance center of anterior teeth more mesial and allows for intrusions with lighter forces(24).

Some researchers have examined extrusive forces in lingual orthodontics; they observed labial root movement when extrusive mechanics were used only in cases where incisors were proclined more than 20 degrees in the occlusal plane. In all other inclination values, lingual root movement was observed with extrusive mechanics.(25)

When evaluated in the vertical plane, applying intrusive forces to maxillary incisors with lingual mechanics results in a force that is close to the long axis passing through the tooth's resistance point. However, in Class II division 2 malocclusions where the crown tilts lingually and the root tip tilts labially, the force application point deviates from the line passing through the tooth's resistance center. This increases lingual inclination of the tooth. In cases where the tooth is lingually inclined, the force applied from lingual creates a moment in the clockwise direction, while the force applied from labial creates a counterclockwise moment. In a mandibular incisor with a normal axial inclination, the force applied by lingual mechanics will be closer to the long axis passing through the resistance center, resulting in more effective intrusion compared to the force applied from the labial surface. (21)

The transverse changes observed during lingual orthodontic treatment involve the more expansive functioning of lingual appliances.(23) Expansion of the upper arch is achieved more easily and effectively with lingual orthodontic treatment compared to labial orthodontic techniques. This is attributed to the predominantly center-weighted and inward-outward force application. Additionally, the thickness of brackets between the tongue and teeth is believed to create a passive expansion effect.(9,10) Additionally, it is believed that the reduced distance between brackets has a positive effect on expansion. Expansion is achieved without excessive labial tipping of the teeth, and this is attributed to the applied force being more palatal and closer to the center of resistance. (10)

In the horizontal plane, the position of lingual brackets on maxillary incisors is approximately along the long axis of the resistance center. Consequently, unlike labial brackets, there is minimal tendency for rotation when force is applied in the mesiodistal direction.(21)

In labial technique, when posterior teeth are used as anchorage during space closure in extraction treatments, there is a tendency for mesial rotation and anchorage loss in these teeth. In lingual technique, on the other hand, when posterior teeth are used as anchorage during space closure in extraction treatments, there is a tendency for distal rotation in these teeth, strengthening the anchorage. In cases requiring maximum anchorage, lingual appliance systems are more advantageous than labial appliance systems. Additionally, during retraction, thick wires should be used to prevent the "bowing effect" in both the vertical and transverse planes.(23)

In standard bracket lingual systems, one of the most significant biomechanical challenges is controlling the inclination of the anterior teeth during the retraction phase. In the vertical plane, the distance between the lingual bracket and the center of resistance is greater than the distance between the buccal bracket and the center of resistance. Therefore, during the retraction movement in lingual orthodontics, more moment is generated, making it challenging to maintain stable incisor torque throughout the retraction process.(26,27)

In several in vitro investigations (28,29), the torque control capabilities of fully customized lingual appliance systems were compared with other combinations of lingual brackets and arch wires, and the results showed that optimal torque control is achieved with custom-designed lingual appliances characterized by an excellent fit between the bracket slot and arch wire.

2.3.1. Anchorage Control in Lingual Orthodontics

Anchorage control in orthodontics refers to the management of tooth movement and control of unwanted tooth movement during treatment. In lingual orthodontics, tooth movement is limited to the teeth that are being corrected, and unwanted tooth movement should be avoided to prevent the teeth from shifting out of position. Anchorage control is achieved through a combination of mechanical and biological means, such as using dental appliances, intraoral devices, and surgical procedures. The use of these techniques helps to ensure that the teeth are properly aligned and stabilized during treatment, leading to a more predictable outcome and a successful orthodontic treatment.

In cases treated with extraction loop mechanics, Takemoto (30) observed that the anchorage value in lingual cases was higher in the posterior dentition group compared to labial cases. This was explained by the closer proximity of the tooth's center of resistance to the lingual bracket. Furthermore, during space closure, the applied force induces a slight buccal root torque and distopalatal rotation of the molar, contributing to the development of cortical bone anchorage.

When sliding mechanics are used on the arch, it has been determined that there is a significantly higher amount of anchorage loss in individuals treated with conventional labial orthodontics compared to those treated with lingual mechanics (31). In cases treated with lingual technique, no significant difference in anchorage loss was found in the extraction of the first and second premolars. Anchorage loss is defined as a multifactorial response associated with the extraction region, appliance type, age, amount of malocclusion, and overjet. The mechanical type can also be considered a source of anchorage loss.

When lingual orthodontic mechanics are employed, retraction of the lower anterior teeth is generally performed as "en masse," involving the entire mass as a whole. When evaluated as an anchorage requirement, if sliding mechanics are used in lingual procedures, it is recommended to employ the "six keys to anchorage control in lingual sliding mechanics" to achieve maximum anchorage control.

The six keys to anchorage control in lingual sliding mechanics (31,32) are as follows:

Palatal Root Torque: In addition to the standard lingual bracket jig system for the front teeth, a slight extra palatal root torque should be applied. Molar tubes should be positioned more mesially to achieve molar tip-back, rather than being placed in the center.

Sliding Mechanics with Two-Dimensional Arch wires: Sliding mechanics should be used with two-dimensional arch wires that have a square front and a rounded back to reduce friction. Alternatively, standard arch wires with wider slots in the back can be used with brackets.

Bite Stops for Molars: Bite stops should be placed on the posterior teeth to open the bite.

Use of Light Forces: Light Class I, II, or III forces can be employed for retraction or closing spaces.

Second Molars as an Anchorage Unit: Second molars can be utilized as an anchorage unit.

Enhanced Curve of Spee in Maxillary Closing Loops: The exaggerated curve of Spee in maxillary closing arches should be increased.

2.3.2. Direct Bonding Techniques

In lingual orthodontic applications, brackets can be directly bonded to the lingual surfaces of the teeth (33). Philippe 2D self-ligating lingual brackets, developed for direct application, can be placed on the lingual surfaces of the teeth using acid, bonding, and composite application similar to labial techniques. The utilization of these brackets is recommended for non-extraction orthodontic treatment in adults with mild to moderate crowding (34).

In lingual orthodontics, transmitting the planned force to the tooth in the closest proximity to the center of resistance is of primary importance. Therefore, due to significant variations in the lingual surface for each individual and tooth, the placement of the bracket will also vary. Therefore, there is an incredible requirement for technical precision. Dr.Schulhof emphasizes this consideration with torque movement example(35). In the production of non-custom orthodontic appliances, there are processes such as tumbling or polishing brackets that may result in suboptimal slots. On average, the tolerance or "slop" between a full-sized arch wire and a slot can permit up to 14 degrees of torque play. When this 14-degree play is applied on the facial side, it leads to a minor incisal edge discrepancy of 0.2 mm, which is negligible and can be addressed with minor enameloplasty. However, when considering the same 14 degrees of play from the lingual application point, the incisal edge discrepancy can range from 1 to almost 2 mm, depending on the bracket's dimensions (35). Therefore, orthodontists often opt for the indirect bonding technique to achieve proximity to the center of resistance and may even prefer customized bracket systems.

2.3.3. Indirect Bonding Techniques

The precise placement of brackets is essential for the successful outcome of lingual orthodontic treatment.(36) The challenges posed by limited access to lingual tooth surfaces, the steeper incline of these surfaces in comparison to the labial ones, and their unique anatomical features make it a demanding task to directly bond lingual brackets in their ideal positions. (36) Since the effectiveness of the treatment largely hinges on the accuracy of bracket placement, the practice of using indirect bonding is more commonly favored in lingual orthodontics. (37) In the indirect bonding method, orthodontic brackets are first positioned on a dental model and are subsequently transferred to the patient's mouth, where they are attached to a tray.(38) This approach has been suggested as the preferred bracket placement technique for both lingual and labial orthodontics.(39) The indirect setup for lingual brackets can be achieved using various systems, such as the CLASS System, the TARG System, Creekmore's slot machine, the Hiro technique or the Orapix System.

2.4. Laboratory Procedures and Application

-CLASS

The Custom Lingual Appliance Setup Service (CLASS) was created by Ormco and relies on precise articulated stone casts.(40) The initial model of malocclusion is first duplicated and then divided into segments, and the teeth are placed in wax to achieve an ideal occlusion. A flat metal plate assists in the placement of anterior brackets, while a separate posterior device is used for positioning brackets on the posterior teeth, ensuring that all slots run parallel to the occlusal plane. The brackets are later returned to the malocclusion model using the cap technique. The acrylic cap here covers the incisal edge of the tooth and overlaps with the bracket.

The advantage of CLASS system is visualization of the treatment result with the set-up and owing to this, being able to foresee the premature contacts and potential residual spaces for extraction cases.(41) However, due to the need of numerous laboratory procedures, this system is quite complex, costly and has a lower degree of accuracy.

-TARG

Ormco originally developed the Torque Angulation Reference Guide (TARG), a surveying instrument, which was later modified by Fillion. This tool serves to transfer the positioning of lingual brackets from the labial surface of the teeth , as well as making it possible to prescribe the torque and angulation for each tooth individually.(42) This process results in a simulated set-up, allowing for the bonding of brackets onto the malocclusion model. Each bracket is equipped with a unique resin-modified base. The TARG instrument cannot compensate for labio-lingual thickness variations in bracket placement. Consequently, in the later stages of treatment, it may be necessary to revisit and reapply the first and second order bends. (41)

-BEST

Bonding with Equal Specific Thickness System is developed by Fillion in 1986. A digital caliper feature for measuring thickness has been added to the original TARG machine because it was realized that there is a lack of measurement for the distance of the tooth's labial surface in the horizontal plane. (41) Measuring the labio-lingual thickness of anterior and posterior teeth has made it easier to use straight-wire technique. In this system a set up model isn't required because the placement of the brackets are on the initial malocclusion model. A specialized software program has been developed by Fillion to create custom arch wires for each patient, taking into account data collected during bracket placement, including factors like torque, angular height, and thickness. This computer-assisted tool is referred to as DALI (dessin de l'arch linguale informatise). The novel laboratory technique, which incorporates the Electronic TARG and DALI software, is named the BEST system. The most significant advantage of this system is that it eliminates the need to coordinate upper and lower arches in the clinic because this coordination is carried out by the computer, relieving the clinician from this task.

-Slot Machine

Thomas Creekmore designed the "slot machine" to enable the placement of both lingual and traditional brackets on a malocclusion model. The procedure consists of positioning each tooth to a prescribed torque and angulation; the machine orientates the bracket slot with the Andrews labial arch wire plane (LA plane).(43) The slot machine is suitable for the placement of brackets featuring arch wire slots accessible from either a horizontal or vertical direction. (44)

-Lingual Bracket Jig System (LBJ)

Geron's Lingual Bracket Jig (LBJ) is the exclusive system that offers the capability for both direct and indirect bracket positioning. It encompasses six jigs designed for the anterior upper teeth, a universal jig for the posterior teeth, along with a specialized ruler. An occlusal stop measures the height of the bracket from the incisal edge. It can be used with the new Scuzzo-Takemoto brackets (STb) as well as with any horizontal slot brackets. Its primary disadvantage is the restricted availability of prescription jigs. (45)

-Transfer Optimized Positioning System

In the TOP system, the setup technique closely resembles that of the BEST system, incorporating the use of a CAD/CAM program. This approach facilitates direct work on the malocclusion model, allowing for the optimal positioning of brackets at the required height (46). During the determination of bracket positions on the malocclusion model, emphasis is placed on positioning the brackets as close as possible to the lingual surface of the tooth, irrespective of labio-lingual thickness differences. Unlike alternative techniques, there is no preparation of acrylic resin to compensate for thickness variations, necessitating the use of arch bends. Arch wires for treatment are meticulously crafted with the aid of a computer-connected robot, specifically the Orthomate lingual module. Although the laboratory time involved may be extended, the time spent with the patient is minimized. Notably, each bracket for every tooth, along with its base, is individually manufactured in gold casting, ensuring an excellent fit to the palatal surface of each tooth. When the appropriate arch wires are employed, the bracket seamlessly fits into its slot. The Incognito system by 3M Unitek adopts this comprehensive approach(47).

-Korean Indirect Bonding Set-up System

The KIS system, developed by the Korean Society of Lingual Orthodontics (KSLO) members, utilizes a bracket positioning machine for simultaneous placement of all brackets, offering several advantages. This includes precise bracket placement, eliminating the need for repositioning during treatment. The system ensures minimal resin thickness between the bracket base and tooth surface, allowing effective torque transmission to the roots. Additionally, the KIS system boasts various advantages, such as sensitive bracket placement, avoiding the necessity for bracket repositioning during treatment. Notably, the height difference between front and back teeth brackets results in rapid intrusion in front teeth and excellent torque control. The use of a mushroom bracket positioner alongside this system facilitates accurate bracket inclination, height, and angulation on the patient's setup model, contributing to achieving high treatment standards(25). In summary the KIS system incorporates a bracket positioning device for accurate bracket placement. This method is highlighted for its simplicity and efficiency when compared to other systems(41).

-Hiro

Developed by Kyoto Takemoto and Giuseppe Scuzzo, and produced by Toshiaki Hiro, this technique involves placing brackets on a set-up model using a 0.018x0.025 inch rectangular arch wire. Custom-made transfer trays for each tooth allow direct bracket transfer from the set-up model to the oral environment(21). No specialized equipment is needed, emphasizing the importance of preparing the set-up model for accurate alignment and tooth separation. The simplicity and cost-effectiveness of this method are notable advantages. The chair time during the initial appointment is extended due to individually positioning and bonding each transfer tray to the teeth. If a transfer tray is damaged or if bracket misplacement occurs after bonding, a new tray must be created following the original set-up model guidance.

-Hybrid Core System

The Hybrid Core system, developed by Matsuno(48), involves the use of silicone and composite in the production of indirect transfer trays through a specific method. This combination allows for the balanced positioning of the trays in the mouth and facilitates easy removal of the silicone component from the bonded brackets. In this assembly, the inner part covering the bracket is made of flexible silicone, while the outer part is composed of acrylic.

-Convertible Resin Core Sistem

In this method, a rigid resin material (Duralay; Reliance Dental Manufacturing Company) is employed to create custom-made transfer trays. Elastic ligature is used to secure the bracket and transfer tray together, allowing for reusability if a bracket were to detach and require reattachment. The use of individual carriers for each tooth can extend the duration of the initial session. Additionally, this system also requires the use of a set-up model. (41,49)

-Simplified Technique

The development of the STb bracket system has led to the creation of a technique where brackets can be placed directly on models using a bracket holder or a simple dental tweezer without the need for a setup model, reducing both laboratory processes and costs(41). This system is associated with the STb (Scuzzo – Takemoto brackets) light lingual system (Ormco Corporation, Glendora, CA, USA). Brackets are placed directly on the malocclusion model. The advantages of this technique include cost reduction and shorter laboratory processes. However, due to differences in tooth thickness, compensatory bends may be required in the arch wire during treatment.

-Ray Set

This system positions each tooth as an individual unit, isolating it from the arch to determine first, second, and third-order values within a central control system. It consists of a sophisticated 3D angle measurement control mechanism, incorporating the RTT (Rotation, Torque, Tip) model holder and the Plane Rotation Control template required for the first-order positions of the teeth. Among indirect bonding systems, this is the most advanced(21)

-Orapix System

In lingual orthodontics, the most recent laboratory technique among indirect bracketing methods is the utilization of Orapix technology. The patient's malocclusion model is scanned with an Orapix scanner (Orapix Co., Ltd., Seoul) to create three-dimensional data. Orthodontists can perform a virtual setup on the three-dimensional patient model using the 3-Txer (Orapix Co., Seoul, Korea) computer program, allowing them to make desired adjustments. Angulation and torque values are determined on the three-dimensional digital setup in the computer environment, enabling occlusal adjustments. This information is digitally transmitted to the laboratory, where a rapid prototype machine creates a resin transfer tray.

Real brackets are transferred to the maloccluded model using personalized resin and jigs. Specifically designed jigs, created with the assistance of the 3TXer software, encompass all virtual information and are manufactured using CAD/CAM technology(50). After the technician positions the brackets on transfer trays made of silicone or resin, resin is added to the base of the brackets, and the trays are sent to the orthodontist for the procedure(41). The treatment's final outcome can be visualized on the computer screen and presented to the patient. The primary objective of this concept is to achieve precise bracket placement with computer assistance, reducing the margin of error compared to manual methods prevalent in most other techniques(31,41).

In 2001, Scuzzo et al. introduced the 'Lingual Straight Wire' concept to eliminate bends in the horizontal and vertical planes of the arch wire. They suggested that when brackets are placed closer to the cervix of the teeth, the thickness difference between canines and premolars would decrease, allowing the use of a straight wire. By employing a lingual arch form placed more cervically, they proposed the elimination of mushroom arch wires. Utilizing the Orapix system, Fillion further developed the Lingual Straight Wire technique, based on the digital setup. During virtual bracket placement, adjustments can be made to eliminate the need for arch wire bends in certain areas, allowing for the use of straight wires(51).

2.5 Straight-wire Technique in Lingual Orthodontics

In the 1970s, along with the brackets developed by Fujita, mushroom arch wires began to be used. In these wires, the diameter difference between the canine and first premolar was eliminated through off-set bends.(10) The straight wire technique began to be used in 2001 by Scuzzo and Takemoto. This approach reduced the time spent on bending mushroom arch wires, thus increasing patient comfort. When mushroom arch wires are used, the anterior arch wire segment adjusted to the canines stays away from the lingual surfaces of the incisor teeth. This creates difficulties in torque control and can lead to unwanted movements. In the initial method developed by Scuzzo and Takemoto, the incisor and canine brackets were bonded closer to the gingival line, reducing the need for off-set bends at this level. However, this resulted in significantly reduced inter-bracket distances and control issues.(21,51)

In subsequent years, STb brackets compatible with the straight wire technique were produced. These brackets have thinner bases, especially designed for the anterior region to allow the wire to pass closer to the gingival area. The slot dimensions were also made shorter to increase inter-bracket distances. In the lingual straight wire technique, it is recommended to position the brackets in the premolars and molars in the center of the clinical crown, while in the canines and incisors, they should be placed at the gingival third of the crown.

In the lingual straight wire technique, the use of indirect bonding methods is essential for three-dimensional control. Proper diagnosis and treatment planning are crucial to achieving successful treatment outcomes. Even the use of the direct method during the rebonding of a single tooth can affect treatment results. Therefore, the initial bonding stage and isolation are critical steps that need to be carefully considered in lingual straight wire technique.(51,52)

In recent years, to prevent errors in arch wires and achieve better treatment outcomes, custom-made arch wires have started to be manufactured with the assistance of CAD/CAM technology, controlled by software and produced by robots. These arch wires include first-order bends, while the second and third-order bends are within the bracket slot. In the final stages, if necessary, all these bends can be executed on the wire with the assistance of robots.(52)

2.6. Current Lingual Braces Systems

- Philippe 2D bracket System

The Philippe 2D self-ligating bracket system, developed by Macchi et al. (Forestadent, Pforzheim, Germany), features straight wire designs, distinguishing it from mushroom-shaped wires. The brackets have a maximum thickness of 1.4 mm due to direct welding of the wings onto the bracket. Their smaller size, rounded edges, and smooth texture contribute to enhanced patient comfort. These brackets can be applied directly into the oral cavity or indirectly positioned on the model, providing two-dimensional control in cases of simple misalignments or space discrepancies. (34) Notably, they do not incorporate slots but utilize winglets welded to the bracket base for arch wire stabilization. The winglets can be closed with a Weingart plier and opened with a thin spatula. With four available types (standard twin, narrow single-wing for lower incisors, wide twin, and three-winged bracket suitable for intermaxillary elastic use), they offer comfort for the patient due to their compact size. The primary advantage of Philippe 2D brackets lies in patient comfort; however, they are not suitable for cases requiring three-dimensional control as they lack slots(53).

- STb Braces (Scuzzo Takemoto Braces)

The introduction of STb brackets by Scuzzo and Takemeto (Ormco, CA) marked a significant advancement by facilitating the use of light forces through a design aimed at reducing friction, thus enhancing patient comfort. However, despite their smaller and more comfortable design, these brackets still require indirect bonding. In malocclusions not requiring extraction, planning for STb brackets can be easily done on the malocclusion model without complex laboratory procedures. The latest STb brackets have demonstrated success, particularly in moderately small and short teeth. STb applications increase the inter-bracket distance, proven to shorten working time by applying very light forces and facilitating rapid leveling. In non-extraction malocclusion treatments with STb, the setup process can be directly performed on the malocclusion model, and the treatment can be completed solely with round wires. Such an approach reduces laboratory time, lowering laboratory fees. For extraction treatments, a specialized diagnostic setup model is required. Assuming correct bracket heights, the treatment can be completed using only round wires. This treatment protocol streamlines laboratory procedures, reducing both laboratory fees and the overall cost for the patient(21,54).

In recent years, the same company and clinicians have developed the Alias Lingual Straight wire Bracket System. As self-ligating brackets with square slots, they are argued to offer better leveling of teeth and possess torque values.

- Stealth Lingual Braces System

The Stealth lingual bracket system, introduced by Quadrelli and Veneziani in 2007 (American Orthodontics, Sheboygan, WI, USA), features smaller bracket dimensions compared to other systems, with a wider inter-bracket distance. This design allows thick arch wires to comfortably fit into the slot, contributing to successful torque control(55).

- GC Experience L Braces System

GC Experience L Braces System (GC Experience-L; GC Orthodontics, Breckerfeld, Germany) feature easily openable interactive covers. The bracket wings and covers have a relatively flat profile, and they follow the anatomical surface of the antagonist in the incisor region. The short buccolingual width provides extra inter-bracket distance, enhancing patient comfort. Bracket positioning requires completion in the laboratory(53).

- In-Ovation L Self-Ligating Braces System

The In-Ovation-L self-ligating brackets (Dentsply GAC International, Islandia, NY, USA) are small-sized and provide high comfort for patients. However, their application requires an indirect technique due to the challenges associated with direct bonding.(53)

- Phantom Self-Ligating Braces

Phantom self-ligating lingual brackets (Gestenco International AB, Gothenburg, Sweden) are unique as they are made of polyceramic material, providing transparency, in contrast to other metal lingual brackets. (53)

- Adenta Evolution SLT Self-ligating Lingual Braces

Adenta Evolution brackets (Adenta GmbH, Gliching, Germany) are single-piece brackets that include a cover. The placement of these brackets utilizes indirect positioning aids called smart jigs with the HIRO system. The brackets are adhered in the correct position indirectly with the assistance of these jigs.(56)

- Lingual Liberty

Lingual Liberty is a digital straight-wire lingual braces system by Dr.Fillion. With the 3D technology, the digital set-up is designed. After getting approved by the orthodontist, , the digital positioning of the brackets is done first by using a virtual 0.018 × 0.025 arch wire which serves as a support for placing the brackets. The transfer jigs were designed to reproduce on the malocclusion models the virtual position of the brackets. The Jigs are first built in 3D on the virtual set-up. The brackets are bonded directly to the malocclusion models using the Jigs. Composite is placed on the base of the brackets to bond and form a pad of resin that adapts to the lingual surfaces. Six preformed straight wires are provided for each case: 4 Thermal NiTi and 2 Beta-Titanium.(57)

- ALIAS (Ormco, Orange, CA)

Designed by Dr.Takemoto and Dr.Scuzzo, these passive self-ligating brackets aim to keep the profile low and increase the patient comfort with rounded contours. It’s objective is to keep the friction as low as possible for easier sliding. The system is a straight-wire system to enable the bendings easier for the orthodontist. The slot-size is 0.018x0.018 square slot. (58)

2.7. Customized Lingual Orthodontics

Since its initial introduction, the landscape of lingual brackets and bonding systems has evolved considerably. While there have been notable improvements, none have achieved a 100% satisfaction rate, prompting the need for customized lingual bracket designs. In the contemporary orthodontic arena, many systems have emerged to address this demand, specializing in the production of lingual brackets and arch wires tailored for individual patients such as Incognito (3M Unitek), Harmony (American Orthodontics), E-brace (Guangzhou Riton Biomaterial), InBrace (Denver,CO), Saklıtel (Istanbul,Türkiye) and Win (DW Lingual Systems). These systems represent a dedicated effort to meet the unique requirements of patients seeking personalized lingual orthodontic solutions.

In the late 1980s, Didier Fillion combined the BEST system (Bonding with Equal Specific Thickness) with a computer-based program called DALI (Dessin d'Arcs Lingual Informatise) to design a personalized arch wire template. Subsequently, the lingual straight wire technique, based on a digital set-up model by Orapix (Orapix Co., Ltd., Seoul), was developed (59).

Wiechmann elucidated the production stage of individually designed arch wires as part of the lingual treatment concept in 1999. The Orthomate system (Orametrix, Dallas, TX, USA) facilitates the production of personalized arch wires using CAD/CAM technology and a computer-controlled bending robot. This robot possesses the capability to precisely bend various arch wire materials (SS, NiTi, TMA, CoCr) to conform to the lingual arch shape. Super elastic and shape-memory nickel-titanium arch wires, including Copper-NiTi and Neo-Sentalloy, can be custom-made with individual 2nd and 3rd order bends. To prevent these wires from losing their shapes after computer-controlled bending, they require heat treatment, which is accomplished through reprogramming using Orthoterm/Orthomate (Orametrix, Dallas, TX, USA). Wiechmann further enhanced this system, leading to its acquisition by 3M Unitek in Monrovia, California, and its renaming as Incognito (46,47).

Alfredo Gilbert developed the LAMDA (Lingual Arch wire Manufacturing and Design Aid) system to design and bend individually produced arch wires(60). Fillion used the Orapix system (Orapix Co., Ltd., Seoul) to develop the Lingual Straight Wire technique, applying a digital set-up (59). Sure Smile (OraMetrix, TX, USA) enables the integration of Cone Beam Computed Tomography (CBCT) images to create a virtual set-up and allows the use of robotically prepared custom arch wires in the final stages of orthodontic treatment (52,61).Sure Smile can also accommodate the use of individually designed arch wires when conventional lingual brackets are employed. Initially, CBCT images are sent to the laboratory to create a diagnostic set-up and digital model. Subsequently, after bonding with conventional lingual brackets, the leveling phase is executed. In a second step, intraoral scans or CBCT images are recorded for treatment planning and a set-up. Once approved by the clinician, custom arch wires are robotically bent in three planes to achieve the desired final outcome (61).

- Incognito (3M Unitek, USA)

The approach developed by Dirk Wiechmann in 2001,later taken over by 3M company, represents a technique utilizing CAD/CAM processes and crafted from a non-allergenic gold alloy(62). This involves the customization of bracket bases and slots for individual teeth, followed by the creation of a series of patient-specific arch wires using robotic systems. The system discourages manual wire bending during production to uphold the technique's effectiveness. Bracket thickness is reduced and provides entirely personalized first-order bends on the arch wire(62).

A silicone impression is obtained and scanned with a three-dimensional scanner. A technician designs the digital bracket bases for each tooth, taking into account the severity of misalignment(63). The technician places each bracket in its base, and the program automatically levels the slots in the real arch wire plane (63).

Modern CAD/CAM technology enhances the precision of lingual orthodontics(46). The Orthomate/Orthoterm system independently calculates and produces individual lingual arch wires, significantly shortening the sequence and duration of lingual treatment. Customizable second and third-order bends can be programmed into the arch wire.

During the following years, Dr.Wiechmann improved and modified this model, introducing his new product, the WIN Lingual Systems.

- Harmony (ASO International, Inc, Tokyo, Japan)

The Harmony personalized lingual bracket system, developed in 2010 by American Orthodontics , is a CAD/CAM-supported system that, similar to the Incognito personalized lingual bracket system (3M Unitek, Monrovia, Minnesota, USA), involves scanning the malocclusion model to transfer it into a computerized environment. Through specialized software, custom brackets and wires are produced for each individual. The primary advantage of the system lies in its hinged design, minimizing chair time(64).

- E-brace (Guongzhou Riton Biomaterial, China)

Similar to the Incognito system, it follows comparable production stages. The use of steel for the brackets contributes to a more cost-effective manufacturing of the appliance. In this system, orthodontists have options such as horizontal and vertical slots, hinged brackets, and a choice between 0.018" or 0.022" slots. The laboratory processes are relatively shorter compared to other systems (65).

- InBrace (Swift Health Systems, Inc., Irvine, CA)

Artificial intelligence algorithms design the tooth movements and aim to give less force according to conventional treatments with the “Gentleforce Technology”. The arch wires are computer designed with loops between all the teeth to enable brushing and flossing. The brackets are low-profile and slimmer with a locked loop design to be friction-free with no sliding. (66)

- BRIUS

The BRIUS technique, introduced in 2017 by Mehdi Peikar, offers a novel approach to fixed orthodontic appliances. BRIUS utilizes proprietary software to conduct Finite Element Analyzes, determining precise force vectors required for optimal tooth movement without relying on practitioner skill. The system comprises two primary components: a horizontal bar and visually striking vertical extension arms. The horizontal bar spans gingivally across the clinical crowns of the teeth from second molar to second molar, while the vertical arms extend individually to engage each tooth. The various convoluted shapes of the vertical arms are determined based on Finite Element Analysis results for each tooth. Following this, the computer generates shapes and rigidities required for the vertical NiTi arms to deliver the calculated force. With a significant engineering process, NiTi arms exhibit less rigidity in the anterior area, intermediate rigidity in premolars, and maximum rigidity in the molar region (67).

- WIN (DW Lingual Systems GmbH, Bad Essen, Germany)

This cutting-edge system is developed by Dirk Wiechmann in 2011. The system, based on the philosophy of three-dimensional computer scanning, seeks to enhance efficient tooth movement by customizing appliance designs according to the lingual surface morphology of each tooth. This process includes adapting bracket bases and slots for individual teeth, and subsequently, generating a set of patient-specific arch wires using robotic systems. The system discourages manual wire bending during production to uphold the technique's effectiveness. Dentists have the opportunity to participate in designing brackets and arch wires during the production phase. Patient comfort is enhanced by ultra-flat designed brackets and providing entirely personalized first-order bends on the arch wire. Customized bracket production offers a broader bonding surface, reducing the risk of bracket detachment. Thinning and positioning the brackets closer to the tooth surface facilitate better torque control and detailing during the finishing stage. The brackets are precision-manufactured to stay within a production tolerance range of 1/1000 millimeter. The slots are designed as "ribbon wise" slot system as vertical slot at the anterior teeth and horizontal slot at the posterior. The slot size is 0,018x0,025. The production time for this system is 7-8 weeks. They also released their self-ligating brackets in 2023, leaving it to the orthodontist to choose.

In the process of creating custom brackets, a two-step polyvinyl siloxane is used to take patient measurements, creating a setup model. This model is then scanned with a high-resolution three-dimensional scanner. The digital model is arranged three-dimensionally along the plane of slot positions, considering the degrees of misalignment and the initial and target occlusions. The WIN technician designs the digital bracket bases for each tooth. The broad base of the brackets allows for direct bonding without the need for a carrier appliance.

The design of all brackets, including slot, wing, hook, and extensive support structures, is accomplished through a CAD/CAM program. These brackets have a low profile compared to traditional lingual brackets, providing optimal adaptation. The low profile allows for precise control in parallel tooth movement, even in cases of severe misalignment or short clinical crowns.

The technician places each bracket in its base, and the program automatically levels the slots in the real arch wire plane. Bracket height, angle, and torque are pre-adjusted in this way, with only first-order adjustments made by the technician. The adjustment of auxiliary hook heights is also crucial. The high-speed prototype machine converts the bracket series into a wax analog. The distance of the bracket from the tooth is crucial in applying torque(35), and these brackets, being very close to the tooth surface, ensure highly successful torque control.

An integral component of the lingual treatment concept is the precise calculation and creation of individual lingual arch wires. Modern CAD/CAM technology enhances the precision of lingual orthodontics(46). This system independently calculates and produces individual lingual arch wires, significantly shortening the sequence and duration of lingual treatment. Especially with the precise adaptation of super elasticity and shape memory materials, the sequence and duration of lingual treatment are considerably reduced(46). Customizable second and third-order bends can be programmed into the arch wire.

2.8. Advantages and Disadvantages of Lingual Orthodontics

2.8.1. Advantages of Lingual Orthodontics

There is no doubt that lingual technique has come a long way from the 1970s to the present day and has reached a level comparable to labial technique in terms of treatment outcomes(68). One of the major advantages of lingual orthodontic treatments lies in its aesthetic appeal(17,55,69–72).

Brackets in lingual orthodontics are positioned on the back surface of the teeth, making them virtually invisible. This characteristic accelerates the acceptance period of the treatment by patients, leading to increased motivation throughout the course of therapy(72,73). Patients undergoing lingual orthodontic treatment have been observed to exhibit better cooperation due to their increased enthusiasm, as noted by Gorman et al. (12)Additionally, even in cases where anchorage is critical, adult patients readily accept interventions such as headgear.

The absence of brackets in the anterior region allows for better monitoring of improvements in tooth alignment(74). Moreover, the lingual placement of brackets enables the assessment of the profile and lips during treatment (70,73,75).

Injuries do not occur on the lips and inner cheek areas(76). This positioning contributes to the prevention of injuries to the lips and buccal regions during sports activities, as emphasized by Fujita(77). Gingival tissues on the visible surfaces remain unaffected when lingual brackets are applied, avoiding hypertrophy and inflammation(74).

The lingual placement of brackets eliminates the occurrence of decalcifications resulting from plaque retention on labial and buccal surfaces. In a study conducted by Van der Veen and colleagues in 2010 (78), 28 patients treated with labial brackets were compared to 28 patients treated with custom lingual brackets regarding white spot lesions. The results revealed that only 4 patients treated with custom lingual brackets showed white spot lesions, whereas 21 patients treated with the labial technique exhibited such lesions. The cleansing effect of the tongue on lingual surfaces aids in the elimination of plaque formation. Studies indicate that the enamel on the palatal surfaces of teeth is more resistant to decalcification, making lingual orthodontic treatments preferable for patients with a higher risk of caries incidence(21,71,79). Initially, frequent bracket breakage was a common issue; however, the reduction in size and angulation of lingual brackets has significantly minimized problems related to retention. This has become a crucial advantage in lingual orthodontics(80). However, during the application of labial brackets, the enamel is exposed to certain chemicals such as etching materials and environmental factors like plaque accumulation, causing potential damage. Even after the removal of brackets and cleaning with bonding agents, remnants may persist between enamel prisms, leading to discoloration of the teeth. In lingual orthodontic treatments, these disadvantages associated with the visible surfaces of the teeth are eliminated(21).

In a systematic review conducted by Long and colleagues in 2013 (81), they investigated the treatment-related side effects between lingual and labial orthodontic treatments. The review, spanning from 1980 to 2012, concluded that there was no significant difference between labial and lingual techniques regarding all pain complaints when evaluated.

Lingual brackets, being positioned closer to the resistance centers of teeth, pose challenges in the generation of unwanted movements(71). This positioning makes it more difficult for undesirable effects to occur, allowing for faster distalization of maxillary molars, as noted by Ronchin(15). Since the resistance center of maxillary molar teeth is near the palatal root, this has been associated with applying force close to the resistance center.

Lingual technique is claimed to have a more pronounced expansion effect compared to the labial technique. The applied force in lingual technique is predominantly centered and from inside to outside. Additionally, the thickness of the brackets leads to the tongue creating an expansive force on the teeth(82). Moreover, the reduced distance between brackets is considered to positively contribute to the expansion. The reason for minimal labial tipping during expansion is explained by the force application point being more palatal and closer to the center of resistance (26).

Lingual orthodontics proves advantageous in preventing complications associated with tongue interference in cases of incorrect swallowing, where tongue intrusion into the extraction area is impossible due to the presence of the arch wire(72,79). Lingual orthodontic treatment is also suggested to eliminate parafunctional habits, such as bruxism or teeth clenching(7,74).

In deep bite cases, the closure speed is expedited with lingual orthodontic treatment(83). Fujita has indicated that lingual orthodontic treatment may be preferred, especially in cases where expansion is required and there is a deep bite issue. The application of force near the resistance center facilitates effective incisor intrusion (24,72,79,83). Additionally, the lingual positioning of brackets on the lingual surfaces of anterior teeth creates incisal contact between upper and lower incisors, inducing a bite-block effect that aids in the correction of deep bites(83).

2.8.2. Disadvantages of Lingual Orthodontics

The practice of lingual orthodontics presents certain clinical challenges(71,83). Direct visibility can be challenging for the orthodontist and difficulties may arise during the placement and removal of the arch wire and ligatures. It has been reported that the time spent at the patient's chairside can increase by approximately 30-50% (84), and in some cases, even up to 100% (85). Due to additional clinical time and laboratory requirements, the costs of treatment are higher especially in standard bracket lingual systems compared to conventional labial orthodontics(12). But with the customization of brackets and arch-wires, both chairside and laboratory procedures for the orthodontist decreases considerably, easing the treatment time and process for the patient.

In a study conducted by Caniklioğlu et al. in 2005, the oral hygiene status of two groups comprising a total of 60 patients treated with labial and lingual techniques was evaluated in terms of factors such as gum bleeding, food impaction, and bad taste perception at the 3rd month of treatment. There was no significant difference between the two groups in terms of oral hygiene. However, patients treated with the lingual technique experienced more problems with food impaction.(86)

In patients, lingual injuries and tissue irritations, oral hygiene problems, and speech difficulties can occur(75,87–90). There is reported to be no significant difference in terms of pain experienced during treatment between patients treated with labial or lingual appliances. The only distinction in the pain experience between the two techniques is that patients using lingual appliances may experience more discomfort on the tongue, whereas patients using labial appliances may experience more pain on the lips and cheeks(91). In studies conducted by Caniklioğlu et al. (86) and Wu et al. (92), patients in the lingual group reported that their biggest challenge was difficulty in speech, whereas Fritz et al. and colleagues (3) stated that the major issue was discomfort in the tongue.

In a study conducted by Hohoff et al. in 2012 (93), speech differences in a total of 34 patients treated with lingual and labial techniques were evaluated using acoustic analysis and sonography. A spectrogram was used for the frequency analysis of the "S" sound. According to the results of this study, in patients treated with the lingual technique, the frequency of the "S" sound significantly decreased after the first month, while the frequency of the labial technique group did not decrease as much. By the third month of treatment, the average frequency value of the labial group reached the initial value, while the lingual group's frequency value remained below the initial value and was significantly lower statistically. This indicates that even after 3 months of treatment, patients undergoing lingual treatment still experience speech disorders. The results of this study are similar to the findings of Hohoff et al. in 2003 (93), where they examined the frequency analysis of the "S" sound in patients treated with lingual technique. (4,83).

In the lingual method, the inter-bracket distance and the radius of the arch form decrease. The reduction in the inter-bracket distance results in an increase in the stiffness of the arch wire. It has been reported that the stiffness of the arch wire made of the same alloy increases by 3.03 in the first and second-order bends and by 1.39 in the third-order bends. Therefore, there are some challenges in mechanical applications during the bending stage for the standard lingual bracket systems(94). In the vertical plane, the distance between the resistance centers of teeth and lingual brackets is greater than the distance between labial brackets. Therefore, during the retraction movement in lingual orthodontics, more moment is generated, and maintaining or correcting the torque of incisors can be quite challenging with standard brackets(26,27).

The diverse morphologies of the lingual surfaces of teeth can pose challenges during the bonding stage of standard lingual bracket application(55,73,75,83). During bracket placement, a minor error in the occlusogingival direction can lead to torque problems, emphasizing the need for careful attention in this aspect(73). In the indirect method, dealing with bracket breakage can be more challenging as it may necessitate additional laboratory procedures for resolution(74,83).

In cases treated with lingual orthodontics, the finishing stage can be challenging(95). Achieving better finishing in lingual orthodontics requires working with gentle forces. However, ensuring three-dimensional control with thin wires can be difficult(96).

2.9. Advantages of Customized Lingual Orthodontics

The development of personalized lingual appliance systems addresses many shortcomings of traditional lingual appliance systems, offering advantages that overcome these deficiencies. Personalized lingual appliances enable clinicians to successfully integrate lingual orthodontic practices into their daily routines. These systems not only provide the most esthetic alternative for correcting malocclusion but also reduce the risk of decalcification and accurately execute individualized treatment plans(97).

The precision and accuracy in the design and manufacturing stages of personalized lingual appliance systems are critical for successful treatment outcomes. Compared to conventional lingual appliance systems, personalized lingual appliance systems eliminate challenges such as bracket losses, difficulties in reattaching brackets, challenges in the finishing stage, and disadvantages in patient comfort(17). The lingual surfaces of teeth exhibit a more irregular structure compared to labial surfaces. During personalized design, the use of digital scans with a resolution of 0.02 mm ensures precision. This precision allows bracket bases to perfectly conform to the lingual surfaces of teeth, enabling a stronger and more secure bond with minimal adhesive agent during attachment(97). Personalized-designed brackets have a lower profile, minimizing interferences and reducing the forces that could lead to bracket detachment.

Moreover, if a rebonding procedure is required, the precise adaptation of the bracket to the lingual surface of the teeth facilitates an easier and more accurate bonding process(17).

The finalization phase of cases treated with personalized lingual appliances can be achieved more easily and as desired. According to Wiechmann et al., three problems contribute to the difficulty of finishing an orthodontic case: incorrect bracket position, improper arch wire fabrication, and mismatch between the bracket and arch wire. However, in the design and production stages of personalized lingual appliances, the use of CAD/CAM technology eliminates these potential issues(17). With CAD/CAM technology, bracket bases precisely conform to the lingual surfaces of teeth, ensuring correct bracket positioning. The reduced distance between brackets in lingual orthodontics makes tooth movement challenging with arch wire bends. Again, CAD/CAM technology facilitates the production of arch wires in harmony with brackets, designed specifically for individuals and incorporating specific bends(17,46). In lingual orthodontics, achieving torque control is particularly challenging during retraction of anterior teeth. This is attributed to the greater distance between the resistance centers of anterior teeth and lingual brackets in the vertical plane compared to labial brackets. This increased distance results in a longer lever arm during retraction, leading to an increase in the moment force(98).

Custom-designed arch wires ensure a precise fit with the bracket slot, facilitating the transfer of the required torque values to the brackets. This alignment enables the brackets to be positioned in accordance with the prepared set-up(99).

In custom-designed lingual appliance systems, it is crucial to keep the brackets as close as possible to the lingual surfaces of the teeth to minimize the bracket profile(63). Moreover, the customization of arch wires allows the inclusion of all first-order bends in the arch wire based on treatment mechanics, contributing to the reduction of bracket thickness(97) Studies comparing treatments with conventional lingual brackets and custom-designed low-profile lingual brackets have indicated that personalized lingual appliances offer greater advantages in terms of chewing, speaking, and patient comfort(100,101).

2.10. Digital Models and Evaluation of Treatment Effectiveness

Orthodontic treatments heavily rely on dental models during the diagnosis and treatment planning phases. The assessment of these models provides a three-dimensional understanding of the maxillary and mandibular dental arches along with their occlusal interactions(102).

Historically, the most common method used for this purpose has been cephalometric film evaluation. However, precise assessment is challenging due to the superimposition of right and left dental arches on the film(103).

Plaster models serve as a reliable diagnostic record, allowing for various analyzes such as arch asymmetry, degree of misalignment, malocclusion classification, Bolton analysis, and more. However, model analysis is a time-consuming procedure(102,104). Orthodontists can also share these models with their colleagues for educational, evaluative, and research purposes, and they can use them to present treatment outcomes to their patients(105).

There are some disadvantages associated with plaster models, including the need for suitable storage space due to the risk of breakage, difficulties in information exchange over long distances, and the possibility of bacterial and fungal accumulation during storage.(106,107)

In recent years, with the advancement of three-dimensional recording systems, digital dental models can be created. Digital models obtained at different times can be overlapped in the same coordinate plane, allowing precise measurements of changes occurring during orthodontic treatment processes(108).

The use of digital models is increasing rapidly today. Digital models can be analyzed with specialized software, and the results can be instantly displayed on a computer screen(109). Digital dental models offer advantages such as diagnostic accuracy, rapid data acquisition, easy information storage, and the ability to share data over the internet(110).

Various methods can be employed to obtain three-dimensional digital dental models, including the scanning of plaster models or measurements, CBCT data, and intraoral scanning of the dentition directly (111–113).

The purpose of the study conducted by Sousa et al. in 2012 was to evaluate the reliability of measurements made on digital dental models obtained using the 3Shape D250 scanning device (3Shape A/S, Copenhagen, Denmark). There was no statistically significant difference found between measurements made directly on plaster models and those made on digital models. The study concluded that linear measurements on digital models are accurate and repeatable, and measurements of arch width and length on digital models are reliable(114).

In a study conducted by Alcan et al.175, they investigated the effects of different storage times of alginate impressions on the accuracy of digital models. A 3Shape D250 scanning device (3Shape A/S, Copenhagen, Denmark) was used to obtain digital models. Out of 105 alginate impressions, 21 were immediately used to create plaster and digital models, while plaster models and digital models from the remaining impressions were obtained 1, 2, 3, and 4 days later, respectively. Deformation occurring in the alginate impressions over time was also evaluated. The study concluded that digital models are as reliable as plaster models(115).

Zilbermann et al., conducted a study comparing the accuracy of measuring tooth size and dental arch width between traditional plaster models and digital models created using OrthoCad (Cadent Inc, Carlstadt, NJ). They found that both methods demonstrated clinically acceptable levels of accuracy and repeatability (116).

Santoro et al. conducted a study comparing the accuracy of measuring tooth size, overbite, and overjet between traditional plaster models and digital models created using OrthoCad (Cadent Inc, Carlstadt, NJ). They found statistically significant differences in tooth size and overbite measurements, with smaller measurements recorded on digital models. However, these differences were deemed clinically insignificant. On the other hand, no statistically significant difference was noted in overjet measurements (117).

A study aimed to compare 3-dimensional printed and conventional setups using ten sets of pretreatment plaster models. Digital replicas were obtained through scanning, and both conventional and virtual setups were constructed based on the treatment plan. The study conducted by Guzman et al. concludes that 3-dimensional setups printed with fused deposition modeling are not comparable to conventional setups, emphasizing the need for careful management in the digital setup process(118).

In a study conducted by Grauer and colleagues in 2011, they used digital model superimposition to evaluate the treatment effectiveness of 94 patients treated with the Incognito lingual appliance system (119).

In a study conducted by Kravitz and colleagues in 2008, they compared the digital set-up model and digital treatment end model of 37 patients in order to evaluate the effectiveness of Invisalign clear aligner treatment(120).

In a study conducted by Pauls and colleagues in 2010, they utilized digital model superimposition to assess the treatment effectiveness of 25 patients treated with the Incognito lingual appliance system (121).

The retrospective cohort study conducted by Pauls et al. aimed to evaluate the accuracy of the completely customized lingual appliance WIN through a three-dimensional (3D) comparison between the setup and the final result. Digitalized models of 20 patients with various malocclusions were analyzed using a 3D scanner. The study found that for incisors, angle discrepancies between the setup and the final result were less than 3° (torque, tip, rotation), and translations showed mean values less than 0.3 mm. Slightly higher values were observed in the lateral segments for rotations and translations. The study concluded that the completely customized lingual appliance WIN allows achieving the final result predicted by the setup with high accuracy(122).

The objective of this retrospective study by Fontinha et al. was to evaluate the efficacy of lingual orthodontics by comparing setups and post-treatment casts in 32 consecutive patients treated with a customized lingual orthodontic appliance. The analysis included various parameters such as overjet, overbite, molar and canine relationships, intercanine, interpremolar, and intermolar distances, arch lengths, midline deviation, bucco-lingual angulation, and mesio-distal angulation. Statistically significant differences in bucco-lingual torque were observed between setups and post-treatment casts, particularly in upper lateral incisors, canines, premolars, and molars, as well as lower incisors and molars. However, the clinically significant torque difference was noted only for upper second premolars and molars. Overall, customized lingual appliances demonstrated efficient control of mesio-distal angulation in anterior teeth, with specific torque variations in certain posterior teeth. Arch widths showed no significant variations, except for specific inter-second premolar and intermolar distances in the upper arch(123).

The objective of this study by Pauls et al.was to verify the therapeutic accuracy of the Incognito bracket system. Therapeutic set-up casts and final treatment casts were digitalized and superimposed using a 3D scanner, and deviations in rotation and translation of each tooth in three spatial dimensions were calculated. The results indicated that front teeth exhibited rotations of less than 4.6° and translations under 0.5 mm. Various factors such as upper or lower jaw, growth, type of tooth, anterior tooth position, bracket generation, 3D scanner hardware, and finishing arch wires were analyzed for their influences. The study concluded that the clinical impression aligns well with the measurements, confirming that lingual orthodontic treatment using individualized brackets yields satisfactory correlation with therapeutic set-ups(121).

A study conducted in 2021 aimed to assess the outcome quality of subjects treated with a completely customized lingual appliance (CCLA) using the ABO Objective Grading System. A retrospective single-arm study included 66 consecutively debonded CCLA cases treated at Hannover Medical School. The initial discrepancy index (DI) was assessed on plaster casts, and the OGS was scored for both set-up and post-treatment casts(124).

The study conducted by Zhang et al. assessed the accuracy of moving anterior teeth with clear aligners using three-dimensional digital models. Results showed minimal discrepancies in crown positions (0.376 ± 0.041 mm maxilla, 0.398 ± 0.037 mm mandible) but larger differences in root positions (2.062 ± 0.128 mm maxilla, 1.941 ± 0.154 mm mandible). Clear aligners effectively moved crowns, mainly through tilting motion, but had limitations in root positioning accuracy(125).

The study conducted by Im et al. in 2014 aimed to compare virtual and manual tooth setups in extraction cases by measuring various occlusal parameters and applying the American Board of Orthodontics objective grading system. Results showed that the digital virtual setup model had smaller arch perimeters, lower values for overbite and overjet, and tendencies toward specific tooth angulations compared to the plaster setup model. The American Board of Orthodontics objective grading system evaluation indicated larger deductions for specific parameters in the digital setup. The study suggests that while digital and manual setups yield similar measurements, delicate adjustments are needed in digital setups to address potential issues like proximal and occlusal contacts(126).

The study evaluated the effectiveness of Invisalign orthodontic treatment, focusing on the impact of auxiliaries and staging. Tooth movements, including incisor torque, premolar derotation, and molar distalization, were assessed in 30 patients. The use of attachments as auxiliaries varied within these movements. Efficacy, determined by comparing achieved and predicted tooth movement through laser-scanned models, ranged from 40% to 87%. The study emphasizes the importance of staging and the total planned movement in achieving successful outcomes with Invisalign(127).

The objective of the study conducted by Barreto et al. was to assess the reliability of digital orthodontic setup technology by comparing it with manual setups and models cast at the end of orthodontic treatment. The study included 20 patients, and their initial and final models, along with manual setups and digital setups, were evaluated using linear measurements such as intercanine widths, intermolar widths, and the length of upper and lower dental arches. The results indicated no statistically significant differences among the measures assessed through manual setups, digital setups, and final models. The study concludes that digital setups are as effective and accurate as manual setups, serving as a reliable tool for diagnosing and treatment planning in orthodontic treatments(128).

A study by Charalampakis et al. aimed to assess the accuracy of specific tooth movements with Invisalign in a sample of 20 Class I adult patients. 398 teeth were measured for vertical, horizontal, and rotational movements, along with transverse widths. The study found that horizontal movements of all incisors were accurate, with minimal differences between predicted and achieved amounts. However, vertical movements, especially intrusions of maxillary central incisors, were less accurate, showing a median difference of 1.5 mm. Additionally, all achieved rotations were significantly smaller than predicted, with maxillary canines exhibiting the greatest difference of 3.05°. The study concludes that the most inaccurate movements observed were intrusion of the incisors and rotation of the canines(129).

In a study conducted by Dai et al., the researchers compared the achieved and predicted crown movements of maxillary and mandibular first molars, canines, and central incisors in adults who underwent Invisalign treatment with extraction of four first premolars. Seventeen adult patients were included in the study, and superimposition of pretreatment and posttreatment dental models was performed using various registrations. The results revealed that the actual tooth crown movements differed from the predicted changes. Notably, first molars showed greater mesial displacement, mesial tipping, and buccal inclination, while canines exhibited greater distal tipping and lingual inclination. Central incisors also demonstrated differences in distal tipping, lingual inclination, retraction, and intrusion. The study concludes that the achieved tooth crown movements did not entirely align with the predictions made in the Invisalign treatment plan(130).

2.11. Interproximal Reduction

Interproximal reduction (IPR) in orthodontics, also known as tooth stripping or enamel reduction, has a historical trajectory that dates back several decades. The concept of deliberate enamel reduction between adjacent teeth emerged as a method to address issues related to tooth crowding and irregularities in dental alignment. The technique gained attention around 1944 by Ballard when he used IPR for the anterior teeth. Orthodontists began utilizing manual stripping methods, involving hand instruments to reduce enamel selectively. With technological advancements, particularly in the latter half of the 20th century and the early 21st century, automated systems such as diamond-coated strips and burs, as well as the incorporation of dental handpieces, have enhanced the precision and efficiency of IPR procedures. Despite ongoing debates regarding its indications and potential side effects, interproximal reduction has become an integral component of orthodontic strategies for achieving optimal dental alignment and addressing issues of tooth crowding.

IPR has been a frequently investigated topic in orthodontics due to its broad application in the field. Mechanical enamel reduction methods are commonly used in orthodontics for purposes such as addressing mild to moderate crowding, resolving Bolton discrepancies, shaping interproximal contact points, stabilizing dental arches, and eliminating black triangle spaces.(131)

In a recent study, it has been reported that the majority of orthodontists (66%) routinely apply stripping in their clinics(132). Stripping can be effective in achieving dental alignment in the mandibular anterior region and enhancing post-orthodontic stability by reducing enamel width on interproximal surfaces(133,134). Additionally, stripping can improve the aesthetics of the anterior teeth. An example of this is the removal of black triangles that may occur after aligning crooked segments(135).

2.11.1. IPR Methods

- Abrasive metal strips: This is used for manual enamel reduction, is coated with diamond particles, providing flexibility for easy abrasion between teeth. Manufactured from stainless steel, these burs come in different widths, and can be unidirectional or bidirectional depending on the placement of the diamond coating. These burs can be applied with Mathieu-type spatulas or special holding devices(136).

- Air Rotor Stripping (ARS): ARS is developed by Sheridan(137) in 1985, utilizing rotary instruments. It can be applied to both anterior and posterior teeth's interproximal contact points using various burs. When performing ARS, an indicator wire is initially placed under the interproximal contact point, and the burs are used sequentially. The abrasion bur is moved in the occlusal or incisal direction, and the abrasion process continues until the guide wire can be removed, approximately for 30 seconds(137,138).

- Handpiece-driven abrasive strips: These abrasion strips, coated with diamonds, come in different sizes and are utilized in interdental abrasion, shaping, and finishing. The diamond coating can be on one side or both sides of the strips (139). Advantages of using rotary instrument-assisted stripping strips include not causing harm to soft tissues, achieving a smoother enamel surface compared to ARS, and preserving the adjacent tooth with single-sided strips. However, a disadvantage is that the process takes longer than ARS(136).

- Stripping discs: In a study comparing various stripping methods, Arman et al.(140) found that the use of stripping sandpaper and stripping discs, along with polishing discs, resulted in the smoothest enamel surface. However, it has been noted that when used at high speeds, they can potentially harm the patient's tongue, cheeks, and lips. The use of a disc guard has been recommended to prevent harm, although it has been reported to limit the dentist's field of view. Additionally, it can create deep cuts in the enamel(136).

- Segmental Discs: Unlike stripping discs, these discs operate with a 30° oscillating motion instead of a 360° rotational motion. They are used with a special low speed handpiece attached to a micromotor. With their special design and different working mechanism, segmental discs aim to minimize these disadvantages(139,141).

- Profin System: Profin stripping tips, applied using rotary tools, can be used for interproximal abrasion in addition to shaping interdental fillings. They have a thin, long, and conical structure with particles of 50μ in each type. They are used with a special angldruva attached to a micromotor. With their special design and flexible structure, they prevent damage to both hard and soft tissues (139).

- Sonic Stripping Tips: These stripping tips are used with a special low speed handpiece. To preserve the adjacent tooth, these tips contain abrasive material on only one side. According to a study by Zingler et al., straight sonic tips abrade more enamel compared to convex ones. Limited variety is a drawback due to having only two tip options.(142)

On a PhD thesis conducted by Dr.Sabah(143), 73 extracted premolars were applied IPR on mesial and distal sides. They examined the surface roughness of the handpiece-driven abrasive strips, diamond burs, diamond discs, manual diamond metal strips. They found out the manual diamond metal strips created the roughest surface, whereas the diamond disc group produced the smoothest surfaces. They also stated the roughness decreased after polishing in every method.

3. HYPOTHESIS OF THE STUDY

In contemporary orthodontics, the application of lingual orthodontics with customized systems not only provide convenience for practitioners but also gains increasing popularity. Therefore, further learning and development of this method will contribute significantly to the field of orthodontics.

The null hypothesis of this study is that the set-up provided by the completely customized lingual orthodontic system is perfectly aligned with the results obtained at the end of the treatment. Therefore, the aim of this study is to overlap and compare, both angularly and linearly in a three-dimensional context, the set-up created in the treatment planning with the final measurements obtained after treatment.

We will also analyze the resolution of the malocclusion between canine-canine with and without IPR. The null hypothesis on the side asserts that there is no significant difference in crowd-solving outcomes between canine teeth in cases with interproximal reduction (IPR) and cases without IPR.

4. MATERIAL AND METHOD

4.1. Sample Size

This retrospective study was conducted in Yeditepe University Faculty of Dentistry. All the patients were treated with completely customized lingual systems WIN (DW Lingual Systems GmbH, Bad Essen, Germany) in Istanbul. All of the patients were treated by Dr.Didem Aktan Meriç between 2019-2023.The initial malocclusion was not an exclusion criteria. Inclusion criteria were simulated prediction (set-up model) and post-treatment models existing, full arch manufactured. Casts were inspected to exclude the possibility of them having any plaster beads or other flaws, such as broken or incomplete teeth. Exclusion criteria were missing teeth, extraction necessary for the treatment, cleft lip and palate, any syndromes affecting the bone remodeling or cranial complex, patients with restorations done in active treatment time. Any use of intermaxillary elastics, Herbst appliance or bracket failure was not excluded. The study comprised 52 jaws (23 female, 13 male) from 36 finished and debonded patients. Whose mean age at the beginning of the treatment was 32.67 years. 30 of the patients are Class I (40 jaws) , 6 of the patients are Class II (12 jaws). In all patients, the treatment could be performed according to the treatment plan and none of the patients required their therapy to be discontinued.

Our study, utilizing G*power 3.1 software for power analysis, found an effect size of 0.35 based on the evaluation for Incisors (122) (alpha error probability=0.05). Conducting a sample size analysis with a power value of 0.80 resulted in a required total sample size of 52. (Fig. 1)

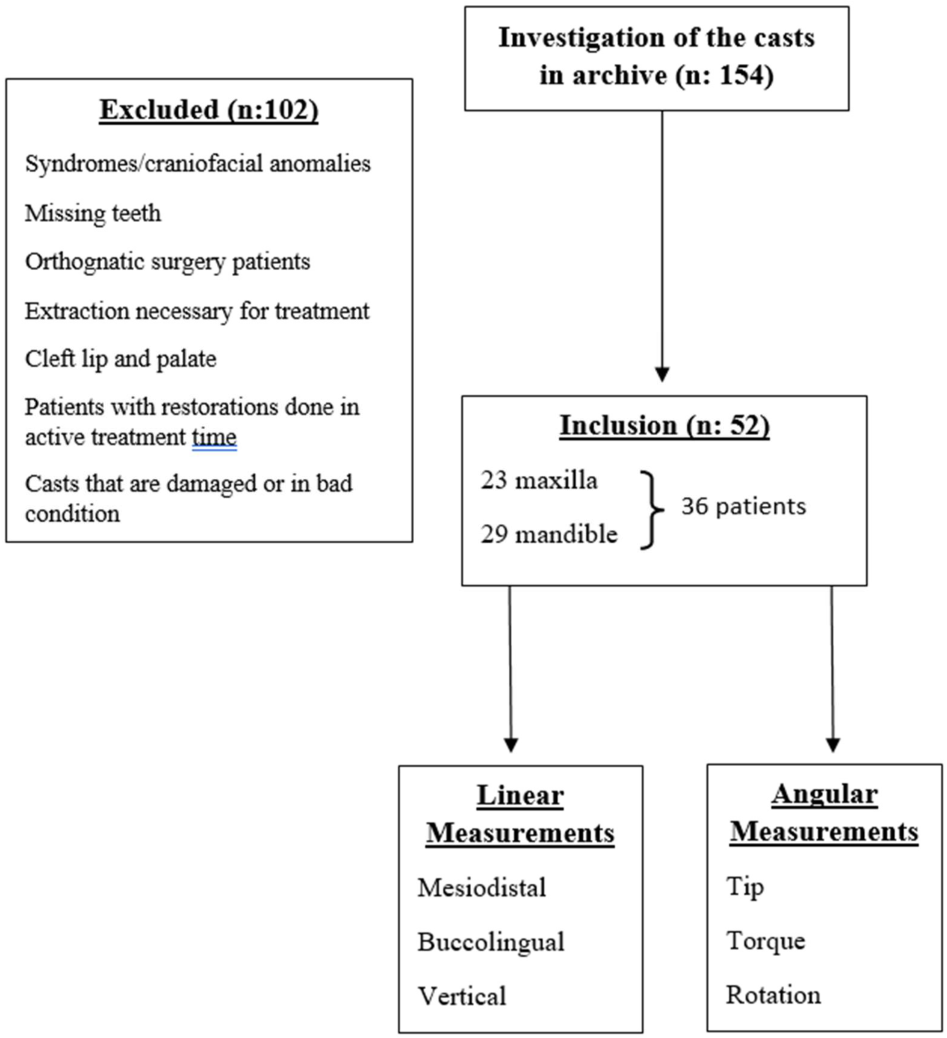

Figure 1. Selection of the sample size

4.2. Treatment Protocol

All patients underwent an initial examination by a periodontist, and dental calculus removal was performed. Following the isolation process, sandblasting with 50 µm Al2O3 was conducted. Etching with phosphoric acid is applied. All cases were bonded with opaque silicon transfer trays provided by the WIN system. All of the brackets were bonded with same chemical cure adhesive system Transbond IDB Pre-Mix (3M Unitek, Monrovia, California, USA) Bonding time took 2 minutes each before taking the tray out. All of the residues were cleaned and dental floss was applied between each tooth.

The arch wire sequence varied between 0.012 super elastic nickel-titanium (SE NiTi), 0.014 SE NiTi, 0.016 SE NiTi, 0.016x0.022 SE NiTi, 0.018x0.025 SE NiTi, 0.016x0.024 stainless steel (SS), 0.018x0.025 SS, 0.0175x0.0175 Beta titanium (B-Ti), 0.017x0.025 B-Ti, 0.018x0.018 B-Ti, 0.018x0.025 B-Ti.

Class II/III intermaxillary elastics were used only in SS arch-wires if needed. After achieving the Class I relationship, brackets of the second molars were debonded and B-Ti arch-wires were placed to add vertical intermaxillary elastics for ideal interdigitation. This procedure leaded this study to eliminate second molars from the analyze.

20 of the jaws (15 mandible, 5 maxilla) had IPR directions on the WIN form between canines. The IPR amount was between 0,2mm-4,2mm (mean 1,78mm for mandible, 0,64mm for maxilla) . The IPR was applied with ARS with carbide burs and/or diamond abrasive strips at the start or during the treatment process when the contacts became ideal for the reduction. Polishing was done with Sof-Lex discs (3M-ESPE Dental Products, USA) in all cases after IPR. If stripping was scheduled in the treatment plan, during setup manufacturing, the exact amount of stripping for each affected tooth surface was noted, and exactly transferred to the patient during treatment by the clinician by verifying with the IPR gauge.

This system is completely customized, meaning the brackets and also the arch wires are all custom manufactured for each patient and each tooth. The slot size is 0,018*0,025 ribbon wise, meaning vertical slot between canine teeth and horizontal slot at the posterior teeth. It provides the planned set-up for the orthodontist to show the patients predicted result. Therefore, at the end of the treatment when the brackets are debonded, we have the chance to analyze the actual finishing and the predicted set-up.

In this retrospective study, the set-up models were created initially from the silicone impression of the malocclusion before beginning the treatment. WIN set-up plans were sent manually by the orthodontist's choice. All of this laboratory process is conducted at the laboratory of DW Lingual Systems in Bad Essen, Germany.

The WIN technicians are trained to keep the canine-canine distance in order to minimize the relapse possibility, unless the orthodontist tells otherwise. The orthodontist fills up the WIN form guiding the technician to add an interproximal reduction (IPR) if necessary for the Bolton discrepancy. Telling all the arch-wire sequences and arranging the Class I/II/III relationship at the end of the treatment is defined by the orthodontist. If IPR is necessary, stripping burs or diamond abrasive strips are chosen.

The final plaster casts were taken right after the removal of the appliance. All of the set-ups and all of the finalized case plaster casts are scanned with the same scanner iTERO Element 2 (Align Technologies,San Jose, Calif).

4.3. Digital Measurements

After trimming the gingival parts from the models, the scanned data were exported as standard triangulation language (STL) files and transferred to GeoMagic Control X 2022 software (3D Systems, Morrisville, USA)(144).

The software applies the best fit algorithm to superimposition the data from both set-up and the final models (Fig. 2). The two models then get automatically matched and maximum compliance was ensured. The two models were adjusted to the global coordinate system. Color map of the superimposition was created in order to better comprehend the tooth positions (Fig. 3). The scale range was set to ±1mm. The tolerance rate was set ±0.1.

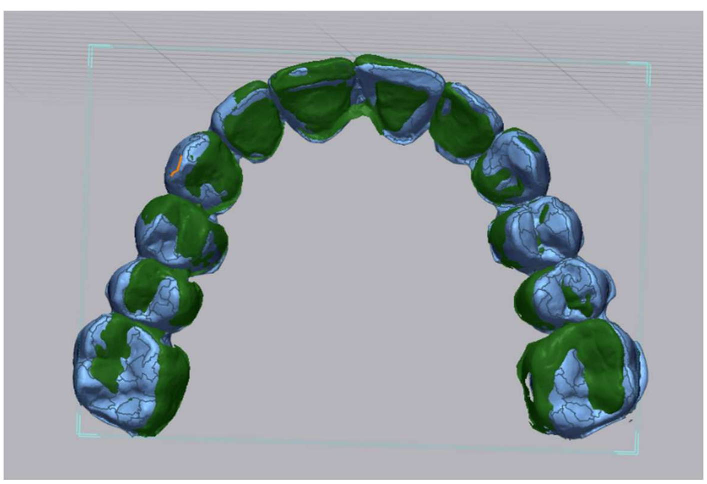

Figure 2. Superimposition of the models (blue: set-up, green: result)

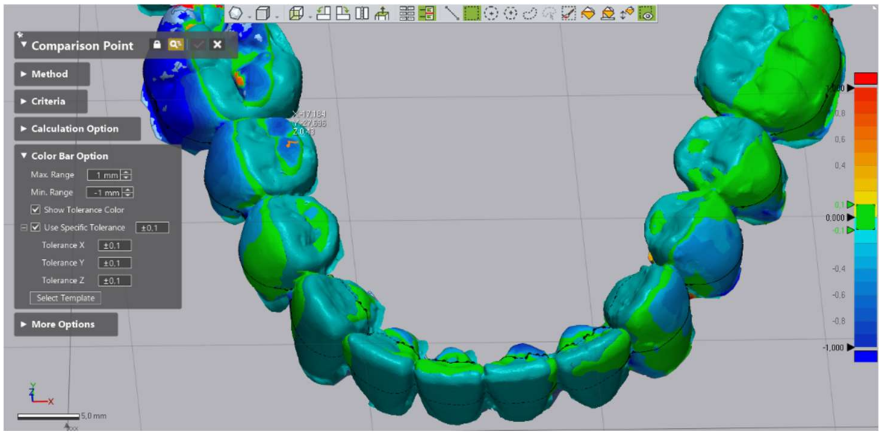

Figure 3. Color map

The rotation, torque, and tip values for each tooth were measured in degrees, while the buccolingual, mesiodistal, and vertical translational amounts were measured in millimeters. The measurements were made from the buccal side of the teeth since it is found risky to analyze the lingual side after the debonding process in case it may have harmed any morphological sections of the teeth. For the measurements, 9984 points were placed in total.

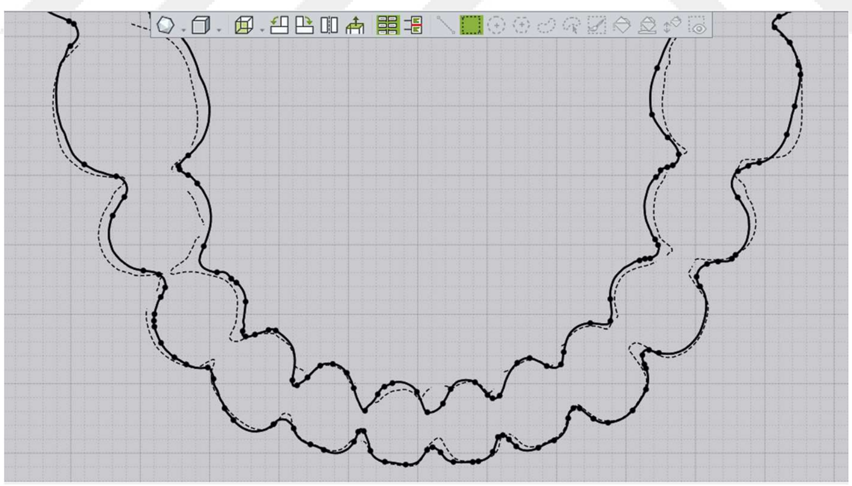

Figure 4. Cross-section in Z plane. Dashed line: final model, straight line: set-up model

Firstly, a cross-section passing through the equatorial line in the horizontal plane was obtained to initiate measurements (Fig. 4). Morphological points that could be distinguished on each tooth, such as tubercules, grooves, incisal edge cusp points, and corners, were identified and individually marked. This process was initially determined and marked on the set-up and then corresponding points were placed on the final model. Following the marking of these points on each tooth, line segments were placed between these points within each tooth. Subsequently, angular measurements between the line segments on the set-up and final models were performed, allowing the determination of the degree of rotation in each tooth (Fig. 5). Each result was recorded in a Microsoft Excel file.

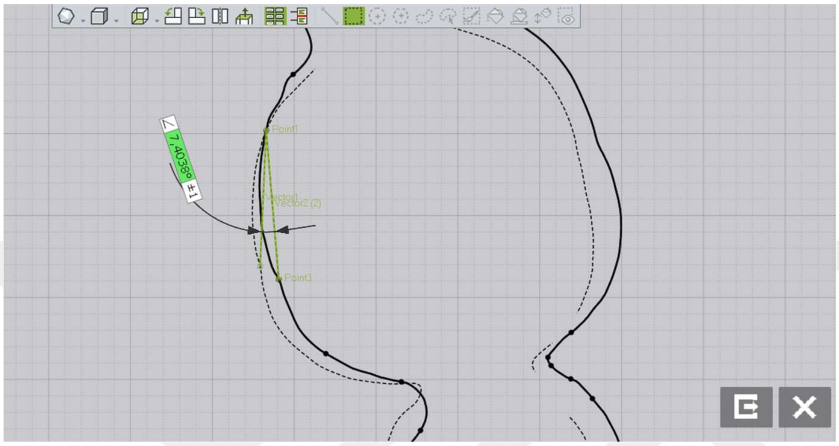

Figure 5. Angular measurement for rotation

Subsequent to rotation analysis, buccolingual translation measurements were made at that same cross-section (Fig. 6). Two consecutive points were placed at the set-up and final model according to the plane which the teeth are positioned. If the tooth is rotated, initially the color map model is examined to decide the tooth positions in buccolingual direction and the mid-point of the vectors which were placed for the rotations were selected (Fig. 7). After comprehension of the tooth positions, points were selected at the models and the linear measurement is done accordingly.

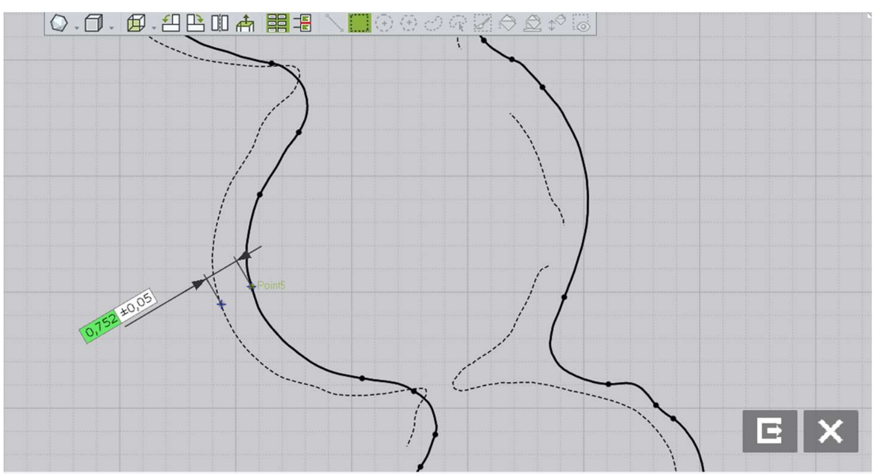

Figure 6. Linear measurement for buccolingual translation

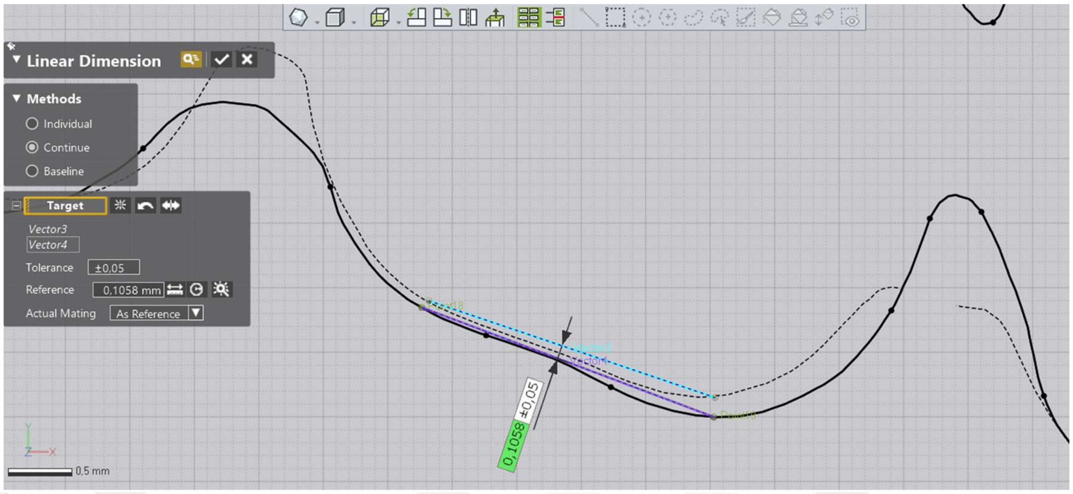

Figure 7. Linear measurement for buccolingual translation of an incisor

For the mesiodistal translation measurements, same cross-section is utilized. Every tooth is analyzed in their own direction following the arch slope. Mesial distances from both models were measured by placing one point each (Fig. 8).

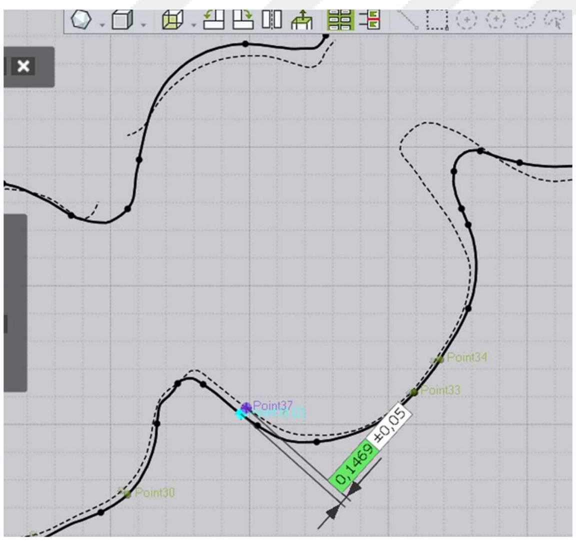

Figure 8. Linear measurement for mesiodistal translation

Subsequently, for the vertical translation and torque measurements, a new cross-section is defined which passes from the sagittal plane of each tooth from the equatorial line (Fig. 9). Two points are placed for each model , one at the incisal tip and one at the equatorial line. A line segment is placed between the two points in each tooth and angular measurements were conducted between the two line segments, which served the torque difference. The linear difference in the tip of the incisal edges were measured in Y-axis to quantify the vertical differences.

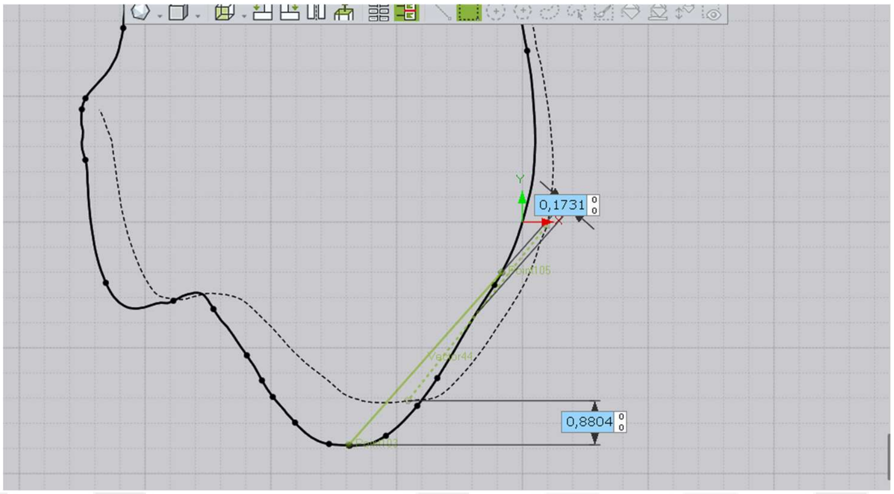

Figure 9. Torque and vertical difference measurements

The tipping for each tooth was studied by placing two points for each tooth on 3D models. Either the most significant parts, such as tips or grooves, or at the middle of the incisal edges and longitudinal axis for each tooth in each model. A line segment is placed between the two points on 3D teeth (Fig. 10-11). These line segments were paired between the set-up and the final model in order to measure the angular differences (Fig. 12). Teeth number 6, 5, 4, 3 were measured from the YZ plane , number 2 and 1 were measured from ZX plane. Each angular measurement was conducted for each tooth and transferred to the Excel file.

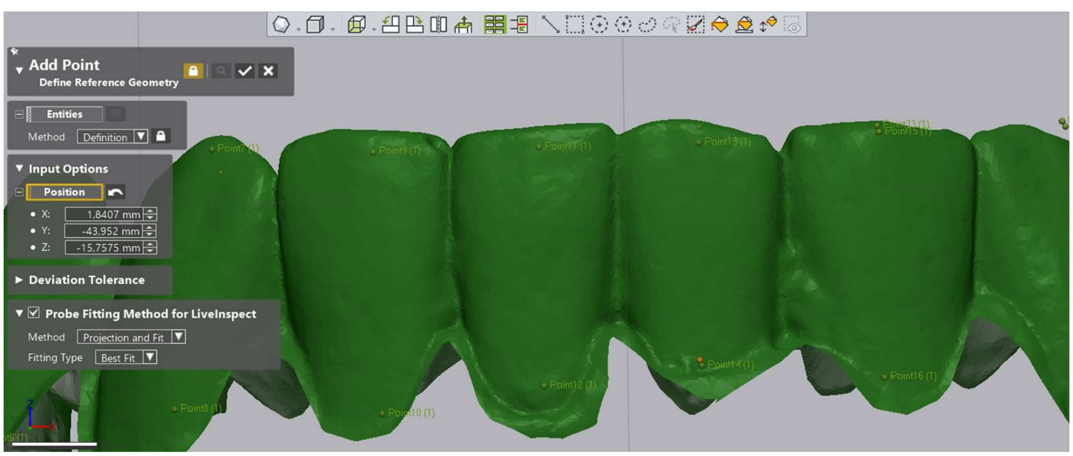

Figure 10. Point placement for the tipping measurements in final model

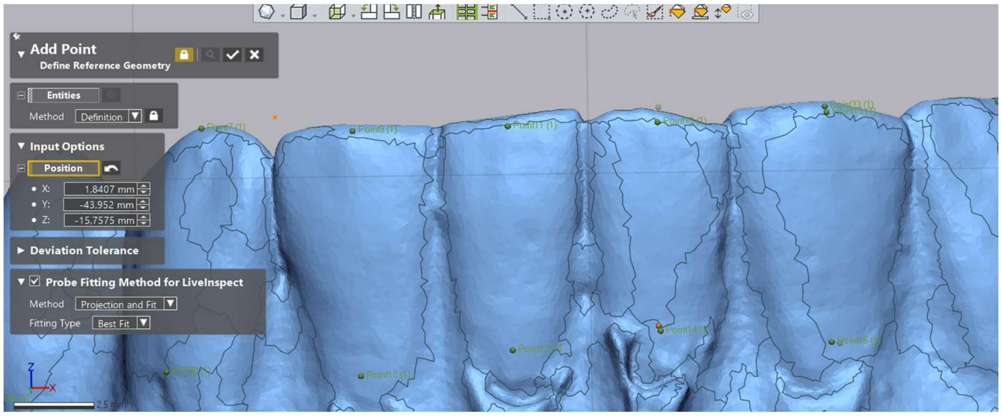

Figure 11. Point placement for the tipping measurements in set-up model

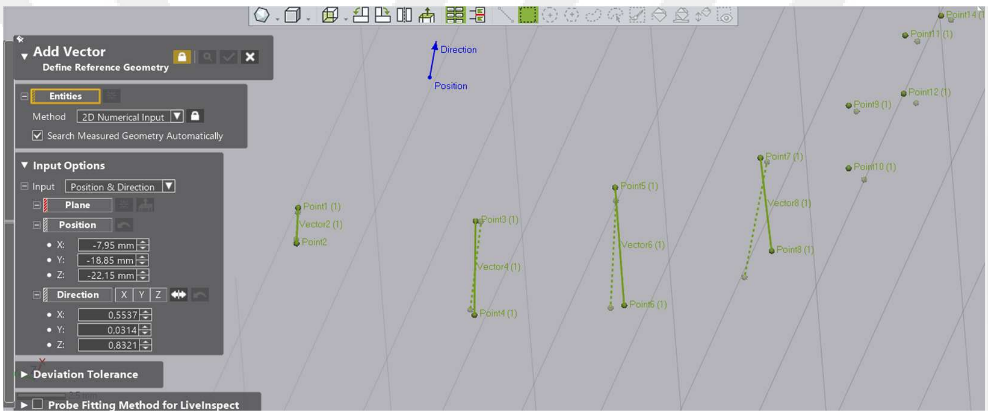

Figure 12. Pairing of the line segments 3D

Ten randomly selected jaws were re-examined 4 weeks after completion of the measurements by the same examiner to assess the reproducibility of the measurements and the accuracy of the method used (Table 1) (121).

Table 1: Results of Methodological Error

		ICC	**(%95 CI)**	**p**
Rotation $(^{0})$	Rotation	0,983	0,975-0,988	0,001*
	Tip	0,976	0,966-0,983	0,001*
	Torque	0,928	0,897-0,950	0,001*
Translation (mm)	Mesiodistal	0,995	0,993-0,997	0,001*
	Buccolingual	1,000	1,000-1,000	0,001*
	Vertical	0,988	0,983-0,992	0,001*

$*p<0.05$

4.4. Statistical Analysis

In evaluating the findings of the study, IBM SPSS Statistics 22 software was employed for statistical analyzes. The normal distribution suitability of parameters was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Descriptive statistical methods (Mean, Standard Deviation, Frequency) were used for data evaluation, and for comparing quantitative data showing normal distribution between two groups, the Student t-test was applied. In cases where parameters did not exhibit a normal distribution, the Mann-Whitney U test was utilized for between-group comparisons. Continuity (Yates) correction was employed in the evaluation of qualitative data. The Spearman's rho correlation test was used to examine relationships between parameters. Class intra-correlation coefficient (ICC) was calculated for assessments related to methodological error. Significance was considered at $p<0.05$ level.

5. RESULTS

Out of a total of 36 specimens, 23 (63.9%) were female, and 13 (36.1%) were male. Among these, 29 were constructed with 624 teeth in the lower jaw, and 23 were constructed with 624 teeth in the upper jaw.

-For the evaluation of measurements based on jaw and tooth type (Table 3), there was no statistically significant difference in rotation measurement between the lower jaw and upper jaw (p: 0.401; $p>0.05$).

There was no statistically significant difference in tipping measurement between the lower jaw and upper jaw (p: 0.955; $p>0.05$).

There was no statistically significant difference in torque measurement between the lower jaw and upper jaw (p: 0.347; $p>0.05$).

There was no statistically significant difference in mesiodistal measurement between the lower jaw and upper jaw (p: 0.651; $p>0.05$).

The average buccolingual measurement difference in the upper jaw was statistically significantly higher than in the lower jaw (p: 0.046; $p<0.05$).

Although the average vertical measurement difference in the upper jaw was higher than in the lower jaw, this difference was very close to significance but did not reach statistical significance (p: 0.052; $p>0.05$).

The rotation measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; $p<0.05$).

The tipping measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; $p<0.05$).

The torque measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; $p<0.05$).

The mesiodistal measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; $p<0.05$).

The buccolingual measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; $p<0.05$).

There was no statistically significant difference in vertical measurement between anterior and posterior teeth (p: 0.683; p>0.05).

-For the evaluation of measurements according to tooth type in the mandible and maxilla, (Table 4) in the lower jaw the average rotation measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).
The average tipping measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).

The average torque measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).

The average mesiodistal measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).

The average buccolingual measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).

The average vertical measurement difference in anterior teeth was statistically significantly higher than in posterior teeth (p: 0.016; p<0.05).

And in the upper jaw the average rotation measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).

There was no statistically significant difference in tipping measurement difference between anterior and posterior teeth (p: 0.602; p>0.05).

The average torque measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).

The average mesiodistal measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).

The average buccolingual measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.001; p<0.05).

The average vertical measurement difference in posterior teeth was statistically significantly higher than in anterior teeth (p: 0.043; p<0.05).

-For the evaluations related to buccolingual measurements in every tooth (Table 5):

Tooth #11: 73.9% were positioned more buccally, and 26.1% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.674; p>0.05).

Tooth #12: 34.8% were positioned more buccally, and 65.2% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.401; p>0.05).

Tooth #13: 26.1% were positioned more buccally, and 73.9% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.263; p>0.05).

Tooth #14: 26.1% were positioned more buccally, and 73.9% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.575; p>0.05).

Tooth #15: 21.7% were positioned more buccally, and 78.3% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.233; p>0.05).

Tooth #16: 26.1% were positioned more buccally, and 73.9% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.234; p>0.05).

Tooth #21: 69.6% were positioned more buccally, and 30.4% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.548; p>0.05).

Tooth #22: 43.5% were positioned more buccally, and 56.5% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.457; p>0.05).

Tooth #23: 30.4% were positioned more buccally, and 69.6% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.894; p>0.05).

Tooth #24: 39.1% were positioned more buccally, and 60.9% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.488; p>0.05).

Tooth #25: 21.7% were positioned more buccally, and 78.3% were positioned more lingually. Although the buccolingual measurement differences in lingual teeth were higher than in buccal teeth, this difference was very close to significance but did not reach statistical significance (p: 0.053; p>0.05).

Tooth #26: 21.7% were positioned more buccally, and 78.3% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.456; p>0.05).

Tooth #31: 62.1% were positioned more buccally, and 37.9% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.393; p>0.05).

Tooth #32: 55.2% were positioned more buccally, and 44.8% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.380; p>0.05).

Tooth #33: 31% were positioned more buccally, and 69% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.203; p>0.05).

Tooth #34: 37.9% were positioned more buccally, and 62.1% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.150; p>0.05).

Tooth #35: 31% were positioned more buccally, and 69% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.777; p>0.05).

Tooth #36: 20.7% were positioned more buccally, and 79.3% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.872; p>0.05).

Tooth #41: 65.5% were positioned more buccally, and 34.5% were positioned more lingually. The buccolingual measurement differences in buccal teeth were statistically significantly higher (p: 0.004; p<0.05).

Tooth #42: 62.1% were positioned more buccally, and 37.9% were positioned more lingually. The buccolingual measurement differences in buccal teeth were statistically significantly higher (p: 0.002; $p<0.05$).

Tooth #43: 48.3% were positioned more buccally, and 51.7% were lingual. The buccolingual measurement differences in buccal teeth were statistically significantly higher (p: 0.023; $p<0.05$).

Tooth #44: 48.3% were positioned more buccally, and 51.7% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.930; $p>0.05$).

Tooth #45: 34.5% were positioned more buccally, and 65.5% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.383; $p>0.05$).

Tooth #46: 24.1% were positioned more buccally, and 75.9% were positioned more lingually. There was no statistically significant difference in buccolingual measurement differences between buccally and lingually positioned teeth (p: 0.221; $p>0.05$).

Table 2: The mean, standard deviation and median values for each tooth in all measurements between set-up and end of treatment

Teeth #	Rotation (⁰)			Translation (mm)		
	Rotation (⁰)	Tip (⁰)	Torque (⁰)	Mesiodistal (mm)	Buccolingual (mm)	Vertical (mm)
	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)
11	0,93±0,70 (1,02)	1,36±0,84 (1,4)	0,82±0,53 (0,85)	0,13±0,10 (0,11)	0,29±0,25 (0,23)	0,33±0,47 (0,18)
12	0,93±0,76 (1)	1,54±0,82 (1,53)	0,79±0,70 (0,69)	0,12±0,11 (0,11)	0,21±0,17 (0,16)	0,33±0,4 (0,16)
13	1,51±1,37 (1,02)	2,18±1,01 (2,14)	0,99±0,73 (0,91)	0,19±0,19 (0,1)	0,25±0,22 (0,19)	0,45±0,46 (0,29)
14	1,77±1,56 (1,26)	1,92±1,37 (1,74)	1,35±1,15 (1,09)	0,17±0,15 (0,12)	0,34±0,28 (0,26)	0,42±0,44 (0,27)
15	2,09±1,4 (1,8)	1,97±1,2 (1,91)	1,38±0,87 (1,09)	0,20±0,15 (0,13)	0,48±0,29 (0,4)	0,42±0,42 (0,25)
16	2,2±1,12 (2,18)	2,00±1,23 (2,02)	1,33±1,03 (1,11)	0,28±0,19 (0,31)	0,78±0,4 (0,9)	0,41±0,44 (0,25)
21	0,91±0,62 (0,88)	1,62±0,82 (1,74)	0,85±0,53 (0,99)	0,14±0,12 (0,09)	0,26±0,2 (0,25)	0,31±0,49 (0,16)
22	1,08±0,92 (0,9)	1,43±0,76 (1,43)	0,78±0,55 (0,93)	0,14±0,11 (0,1)	0,16±0,13 (0,14)	0,35±0,45 (0,26)
23	1,21±0,87 (1,07)	2,12±1,4 (1,89)	1,01±0,61 (0,93)	0,16±0,16 (0,1)	0,19±0,18 (0,15)	0,41±0,39 (0,37)
24	1,6±1,19 (1,48)	1,42±1,17 (1,38)	1,39±1,10 (1,25)	0,14±0,10 (0,1)	0,31±0,24 (0,2)	0,48±0,49 (0,31)
25	1,85±1,3 (1,63)	2,01±1,44 (2,07)	1,51±1,05 (1,47)	0,26±0,19 (0,24)	0,44±0,30 (0,4)	0,40±0,33 (0,26)
26	2,67±1,33 (2,73)	1,77±1,22 (1,55)	1,78±0,90 (1,75)	0,23±0,15 (0,18)	0,76±0,47 (0,78)	0,36±0,30 (0,29)
31	1,10±0,76 (0,95)	1,54±1,05 (1,49)	0,96±1,00 (0,67)	0,14±0,11 (0,14)	0,19±0,18 (0,14)	0,35±0,30 (0,28)
32	1,20±1,01 (1,1)	1,29±0,78 (1,24)	0,99±0,90 (0,8)	0,12±0,14 (0,08)	0,13±0,09 (0,12)	0,37±0,31 (0,28)
33	1,18±0,88 (1,27)	1,95±1,37 (1,81)	0,87±0,64 (0,8)	0,16±0,20 (0,11)	0,15±0,12 (0,1)	0,31±0,33 (0,24)
34	1,66±1,07 (1,58)	2,05±1,19 (1,99)	1,25±0,91 (1,16)	0,18±0,20 (0,15)	0,38±0,39 (0,23)	0,28±0,24 (0,21)
35	2,12±1,37 (2,4)	1,88±1,54 (1,57)	1,73±0,91 (1,59)	0,21±0,17 (0,19)	0,45±0,4 (0,25)	0,23±0,19 (0,18)
36	2,55±1,63 (2,6)	2,29±1,98 (2,16)	1,67±1,24 (1,24)	0,29±0,22 (0,23)	0,65±0,5 (0,46)	0,30±0,26 (0,25)
41	1,11±0,97 (0,67)	1,26±0,69 (1,14)	0,92±0,92 (0,64)	0,14±0,17 (0,07)	0,19±0,16 (0,13)	0,32±0,29 (0,2)
42	1,08±0,87 (0,92)	1,4±1,16 (1,27)	0,92±0,99 (0,62)	0,17±0,2 (0,1)	0,19±0,18 (0,14)	0,37±0,34 (0,27)
43	1,45±0,92 (1,33)	2,02±1,47 (1,72)	0,69±0,71 (0,37)	0,22±0,27 (0,11)	0,23±0,2 (0,14)	0,36±0,36 (0,21)
44	2,1±1,37 (1,74)	2,19±1,33 (2,04)	1,07±1,05 (0,62)	0,25±0,23 (0,19)	0,38±0,31 (0,26)	0,28±0,33 (0,15)
45	1,67±1,23 (1,46)	2,41±1,46 (2,33)	1,29±1,18 (1,02)	0,28±0,26 (0,23)	0,46±0,41 (0,35)	0,28±0,25 (0,21)
46	2,25±1,38 (2,29)	1,91±1,06 (1,68)	1,60±1,05 (1,65)	0,34±0,25 (0,3)	0,64±0,45 (0,52)	0,28±0,34 (0,13)

Table 3: Evaluation of measurements based on jaw and tooth type

	Rotation (^{0})			**Translation (mm)**		
	Rotation (^{0})	**Tip (^{0})**	**Torque (^{0})**	**Mesiodistal (mm)**	**Buccolingual (mm)**	**Vertical (mm)**
	Mean±SD (median)	**Mean±SD (median)**	**Mean±SD (median)**	**Mean±SD (median)**	**Mean±SD (median)**	**Mean±SD (median)**
Mandible	1,62±1,24 (1,35)	1,85±1,33 (1,63)	1,16±1,01 (0,97)	0,21±0,21 (0,14)	0,34±0,36 (0,21)	0,31±0,3 (0,21)
Maxilla	1,56±1,24 (1,28)	1,78±1,14 (1,63)	1,16±0,89 (1,03)	0,18±0,15 (0,13)	0,37±0,34 (0,27)	0,39±0,42 (0,25)
p	0,401	0,955	0,347	0,651	0,046*	0,052
Anterior	1,15±0,91 (1,03)	1,63±1,09 (1,52)	0,88±0,76 (0,8)	0,15±0,17 (0,1)	0,2±0,18 (0,14)	0,35±0,38 (0,23)
Posterior	2,05±1,36 (1,97)	2±1,38 (1,81)	1,44±1,05 (1,25)	0,24±0,2 (0,18)	0,5±0,4 (0,38)	0,34±0,34 (0,22)
p	0,001*	0,001*	0,001*	0,001*	0,001*	0,683

Mann Whitney U Test *$p<0.05$

Table 4: The evaluation of measurements according to tooth type in the mandible and maxilla

		Mandible			**Maxilla**		
		Anterior	**Posterior**		**Anterior**	**Posterior**	
		Mean±SD (median)	**Mean±SD (median)**	**p**	**Mean±SD (median)**	**Mean±SD (median)**	**p**
Rotation (^{0})	Rotation	1,19±0,9 (1,08)	2,06±1,37 (1,97)	0,001*	1,09±0,91 (0,99)	2,03±1,34 (1,97)	0,001*
	Tip	1,58±1,15 (1,41)	2,12±1,45 (1,9)	0,001*	1,71±1 (1,61)	1,85±1,27 (1,65)	0,602
	Torque	0,89±0,86 (0,69)	1,43±1,08 (1,25)	0,001*	0,87±0,61 (0,91)	1,46±1,02 (1,24)	0,001*
Translation (mm)	Mesiodistal	0,16±0,19 (0,1)	0,26±0,23 (0,2)	0,001*	0,14±0,13 (0,1)	0,21±0,16 (0,16)	0,001*
	Buccolingual	0,18±0,16 (0,13)	0,49±0,42 (0,36)	0,001*	0,23±0,2 (0,16)	0,52±0,38 (0,4)	0,001*
	Vertical	0,35±0,32 (0,24)	0,27±0,27 (0,2)	0,016*	0,36±0,44 (0,21)	0,42±0,4 (0,29)	0,043*

Mann Whitney U Test *$p<0.05$

Table 5: Evaluations related to buccolingual measurements between set-up and end of treatment

	Buccolingual (mm)				
	Buccally positioned		Lingually positioned		
Teeth #	**n (%)**	**Mean±SD (median)**	**n (%)**	**Mean±SD (median)**	**p**
11	17 (%73,9)	0,31±0,27 (0,28)	6 (%26,1)	0,24±0,18 (0,18)	0,674
12	8 (%34,8)	0,17±0,14 (0,14)	15 (%65,2)	0,23±0,18 (0,16)	0,401
13	6 (%26,1)	0,16±0,16 (0,14)	17 (%73,9)	0,28±0,23 (0,26)	0,263
14	6 (%26,1)	0,35±0,42 (0,27)	17 (%73,9)	0,33±0,22 (0,26)	0,575
15	5 (%21,7)	0,34±0,13 (0,34)	18 (%78,3)	0,52±0,31 (0,52)	0,233
16	6 (%26,1)	0,63±0,41 (0,53)	17 (%73,9)	0,84±0,39 (0,94)	0,234
21	16 (%69,6)	0,27±0,19 (0,26)	7 (%30,4)	0,22±0,22 (0,09)	0,548
22	10 (%43,5)	0,13±0,11 (0,12)	13 (%56,5)	0,18±0,15 (0,15)	0,457
23	7 (%30,4)	0,16±0,12 (0,15)	16 (%69,6)	0,20±0,21 (0,15)	0,894
24	9 (%39,1)	0,29±0,26 (0,20)	14 (%60,9)	0,32±0,23 (0,21)	0,488
25	5 (%21,7)	0,21±0,17 (0,26)	18 (%78,3)	0,50±0,30 (0,51)	0,053
26	5 (%21,7)	0,59±0,53 (0,33)	18 (%78,3)	0,81±0,45 (0,81)	0,456
31	18 (%62,1)	0,23±0,21 (0,14)	11 (%37,9)	0,13±0,11 (0,10)	0,393
32	16 (%55,2)	0,15±0,11 (0,14)	13 (%44,8)	0,11±0,07 (0,12)	0,380
33	9 (%31)	0,18±0,14 (0,15)	20 (%69)	0,13±0,11 (0,08)	0,203
34	11 (%37,9)	0,36±0,19 (0,31)	18 (%62,1)	0,39±0,47 (0,19)	0,150
35	9 (%31)	0,44±0,40 (0,25)	20 (%69)	0,45±0,41 (0,26)	0,777
36	6 (%20,7)	0,82±0,79 (0,65)	23 (%79,3)	0,61±0,41 (0,46)	0,872
41	19 (%65,5)	0,24±0,17 (0,21)	10 (%34,5)	0,09±0,07 (0,06)	0,004*
42	18 (%62,1)	0,26±0,20 (0,17)	11 (%37,9)	0,09±0,05 (0,07)	0,002*
43	14 (%48,3)	0,32±0,23 (0,29)	15 (%51,7)	0,14±0,14 (0,12)	0,023*
44	14 (%48,3)	0,35±0,21 (0,26)	15 (%51,7)	0,41±0,39 (0,25)	0,930
45	10 (%34,5)	0,33±0,23 (0,35)	19 (%65,5)	0,54±0,47 (0,35)	0,383
46	7 (%24,1)	0,47±0,33 (0,45)	22 (%75,9)	0,70±0,47 (0,61)	0,221

Mann Whitney U Test **p<0.05*

Table 6: Evaluations related to torque measurements between set-up and end of treatment

Teeth #	Torque (^{0}) Protrusive n (%)	Protrusive Mean±SD (median)	Retrusive n (%)	Retrusive Mean±SD (median)	p
11	7 (%30,4)	0,78±0,55 (0,77)	16 (%69,6)	0,83±0,54 (0,94)	0,973
12	9 (%39,1)	0,74±0,70 (0,69)	14 (%60,9)	0,82±0,72 (0,76)	0,900
13	6 (%26,1)	0,98±0,44 (0,98)	17 (%73,9)	1,00±0,82 (0,9)	0,674
14	11 (%47,8)	1,46±1,45 (1,07)	12 (%52,2)	1,25±0,84 (1,15)	0,758
15	11 (%47,8)	1,75±0,95 (1,6)	12 (%52,2)	1,05±0,66 (1)	0,065
16	12 (%52,2)	1,44±1,31 (1,07)	11 (%47,8)	1,21±0,65 (1,17)	0,951
21	5 (%21,7)	1,12±0,35 (0,99)	18 (%78,3)	0,78±0,56 (0,84)	0,333
22	7 (%30,4)	0,89±0,68 (1,11)	16 (%69,6)	0,74±0,5 (0,74)	0,593
23	11 (%47,8)	1,00±0,69 (0,91)	12 (%52,2)	1,01±0,56 (0,94)	0,806
24	10 (%43,5)	1,55±1,26 (1,4)	13 (%56,5)	1,27±0,99 (1,18)	0,577
25	11 (%47,8)	1,55±1,24 (1,29)	12 (%52,2)	1,47±0,89 (1,54)	0,712
26	9 (%39,1)	1,93±0,86 (1,97)	14 (%60,9)	1,68±0,95 (1,69)	0,488
31	8 (%27,6)	1,28±1,62 (0,55)	21 (%72,4)	0,84±0,64 (0,82)	0,845
32	6 (%20,7)	1,65±1,38 (1,56)	23 (%79,3)	0,82±0,68 (0,77)	0,170
33	6 (%20,7)	0,94±0,43 (0,92)	23 (%79,3)	0,85±0,69 (0,56)	0,518
34	8 (%27,6)	0,98±0,85 (0,79)	21 (%72,4)	1,36±0,93 (1,3)	0,306
35	7 (%24,1)	1,40±0,80 (1,14)	22 (%75,9)	1,84±0,93 (1,81)	0,221
36	11 (%37,9)	1,16±1,02 (0,91)	18 (%62,1)	1,97±1,29 (1,72)	0,065
41	8 (%27,6)	1,12±1,34 (0,44)	21 (%72,4)	0,85±0,73 (0,73)	0,922
42	10 (%34,5)	0,96±1,38 (0,37)	19 (%65,5)	0,89±0,76 (0,94)	0,335
43	8 (%27,6)	0,28±0,25 (0,22)	21 (%72,4)	0,85±0,77 (0,75)	0,045*
44	7 (%24,1)	1,46±1,76 (0,58)	22 (%75,9)	0,94±0,71 (0,82)	0,760
45	10 (%34,5)	1,31±1,48 (0,76)	19 (%65,5)	1,28±1,04 (1,24)	0,614
46	7 (%24,1)	1,41±0,90 (1,32)	22 (%75,9)	1,66±1,11 (1,65)	0,683

Mann Whitney U Test *p<0.05*

-For the evaluations related to torque measurements in every tooth (Table 6):

Tooth #11: 30.4% were protrusive, and 69.6% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.973; $p>0.05$).

Tooth #12: 39.1% were protrusive, and 60.9% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.900; $p>0.05$).

Tooth #13: 36.1% were protrusive, and 73.9% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.674; $p>0.05$).

Tooth #14: 47.8% were protrusive, and 52.2% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.758; $p>0.05$).

Tooth #15: 47.8% were protrusive, and 52.2% were retrusive. The torque measurement differences in teeth that were protrusive were higher than in those that were retrusive, but this difference was very close to significance and did not reach statistical significance (p: 0.065; $p>0.05$).

Tooth #16: 52.2% were protrusive, and 47.8% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.951; $p>0.05$).

Tooth #21: 21.7% were protrusive, and 78.3% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.333; $p>0.05$).

Tooth #22: 30.4% were protrusive, and 69.6% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.593; p>0.05).

Tooth #23: 47.8% were protrusive, and 52.2% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.806; p>0.05).

Tooth #24: 43.5% were protrusive, and 56.5% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.577; p>0.05).

Tooth #25: 47.8% were protrusive, and 52.2% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.712; p>0.05).

Tooth #26: 39.1% were protrusive, and 60.9% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.488; p>0.05).

Tooth #31: 27.6% were protrusive, and 72.4% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.845; p>0.05).

Tooth #32: 20.7% were protrusive, and 79.3% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.170; p>0.05).

Tooth #33: 20.7% were protrusive, and 79.3% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.518; p>0.05).

Tooth #34: 27.6% were protrusive, and 72.4% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.306; $p>0.05$).

Tooth #35: 24.1% were protrusive, and 75.9% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.221; $p>0.05$).

Tooth #36: 37.9% were protrusive, and 62.1% were retrusive. The torque measurement differences in teeth that were retrusive were higher than in those that were protrusive, but this difference was very close to significance and did not reach statistical significance (p: 0.065; $p>0.05$).

Tooth #41: 27.6% were protrusive, and 72.4% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.922; $p>0.05$).

Tooth #42: 34.5% were protrusive, and 65.5% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.335; $p>0.05$).

Tooth #43: 27.6% were protrusive, and 72.4% were retrusive. The torque measurement differences in teeth that were retrusive were statistically significantly higher than in those that were protrusive (p: 0.045; $p<0.05$).

Tooth #44: 24.1% were protrusive, and 75.9% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.760; $p>0.05$).

Tooth #45: 34.5% were protrusive, and 65.5% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.614; $p>0.05$).

Tooth #46: 24.1% were protrusive, and 75.9% were retrusive. There was no statistically significant difference in torque measurement differences between teeth that were positioned more protrusive and teeth that were positioned more retrusive (p: 0.683; p>0.05).

Table 7: Evaluations related to vertical measurements

	Vertical (mm)				
	Extruded		Intruded		
Teeth #	**n (%)**	**Mean±SD (median)**	**n (%)**	**Mean±SD (median)**	**p**
11	12 (%52,2)	0,21±0,14 (0,15)	11 (%47,8)	0,45±0,66 (0,21)	0,356
12	9 (%39,1)	0,15±0,14 (0,11)	14 (%60,9)	0,44±0,47 (0,30)	0,101
13	6 (%26,1)	0,47±0,41 (0,42)	17 (%73,9)	0,45±0,49 (0,24)	0,674
14	3 (%13)	0,23±0,14 (0,25)	20 (%87)	0,45±0,46 (0,29)	0,465
15	5 (%21,7)	0,16±0,07 (0,17)	18 (%78,3)	0,49±0,45 (0,37)	0,074
16	5 (%21,7)	0,29±0,27 (0,22)	18 (%78,3)	0,44±0,48 (0,29)	0,502
21	13 (%56,5)	0,21±0,16 (0,16)	10 (%43,5)	0,43±0,71 (0,17)	0,901
22	6 (%26,1)	0,25±0,23 (0,20)	17 (%73,9)	0,38±0,51 (0,26)	0,624
23	2 (%8,7)	0,30±0,24 (0,30)	21 (%91,3)	0,43±0,40 (0,37)	0,827
24	4 (%17,4)	0,33±0,18 (0,32)	19 (%82,6)	0,52±0,53 (0,31)	0,746
25	7 (%30,4)	0,26±0,19 (0,18)	16 (%69,6)	0,46±0,37 (0,40)	0,548
26	11 (%47,8)	0,39±0,33 (0,34)	12 (%52,2)	0,33±0,29 (0,25)	0,498
31	11 (%37,9)	0,30±0,21 (0,28)	18 (%62,1)	0,39±0,34 (0,28)	0,822
32	15 (%51,7)	0,28±0,26 (0,24)	14 (%48,3)	0,48±0,34 (0,44)	0,116
33	9 (%31)	0,15±0,12 (0,14)	20 (%69)	0,38±0,37 (0,28)	0,034*
34	11 (%37,9)	0,24±0,18 (0,17)	18 (%62,1)	0,31±0,27 (0,24)	0,590
35	7 (%24,1)	0,20±0,18 (0,13)	22 (%75,9)	0,23±0,2 (0,19)	0,646
36	10 (%34,5)	0,24±0,18 (0,22)	19 (%65,5)	0,33±0,3 (0,28)	0,551
41	11 (%37,9)	0,25±0,24 (0,19)	18 (%62,1)	0,36±0,31 (0,24)	0,369
42	15 (%51,7)	0,30±0,26 (0,22)	14 (%48,3)	0,44±0,42 (0,38)	0,337
43	9 (%31)	0,22±0,09 (0,21)	20 (%69)	0,43±0,42 (0,26)	0,604
44	9 (%31)	0,14±0,10 (0,18)	20 (%69)	0,34±0,38 (0,15)	0,278
45	10 (%34,5)	0,17±0,11 (0,21)	19 (%65,5)	0,34±0,29 (0,21)	0,215
46	8 (%27,6)	0,12±0,12 (0,08)	21 (%72,4)	0,34±0,38 (0,17)	0,057

Mann Whitney U Test **p<0.05*

-For the evaluations related to vertical measurements between planned set-up and end of treatment (Table 7):

Tooth #11: 52.2% were extruded, and 47.8% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.356; p>0.05).

Tooth #12: 39.1% were extruded, and 60.9% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.101; p>0.05).

Tooth #13: 26.1% were extruded, and 73.9% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.674; p>0.05).

Tooth #14: 13% were extruded, and 87% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.465; p>0.05).

Tooth #15: 21.7% were extruded, and 78.3% were intruded. The vertical measurement differences in teeth with intrusion were higher than in those with extrusion, but this difference was very close to significance and did not reach statistical significance (p: 0.074; p>0.05).

Tooth #16: 21.7% were extruded, and 78.3% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.502; p>0.05).

Tooth #21: 56.5% were extruded, and 43.5% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.901; p>0.05).

Tooth #22: 26.1% were extruded, and 73.9% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.624; p>0.05).

Tooth #23: 8.7% were extruded, and 91.3% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.827; p>0.05).

Tooth #24: 17.4% were extruded, and 82.6% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.746; $p>0.05$).

Tooth #25: 30.4% were extruded, and 69.6% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.548; $p>0.05$).

Tooth #26: 47.8% were extruded, and 52.2% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.498; $p>0.05$).

Tooth #31: 37.9% were extruded, and 62.1% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.822; $p>0.05$).

Tooth #32: 51.7% were extruded, and 48.3% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.116; $p>0.05$).

Tooth #33: 31% were extruded, and 69% were intruded. The vertical measurement differences in teeth with intrusion were statistically significantly higher than in those with extrusion (p: 0.034; $p<0.05$).

Tooth #34: 37.9% were extruded, and 62.1% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.590; $p>0.05$).

Tooth #35: 24.1% were extruded, and 75.9% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.646; $p>0.05$).

Tooth #36: 34.5% were extruded, and 65.5% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.551; $p>0.05$).

Tooth #41: 37.9% were extruded, and 62.1% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.369; $p>0.05$).

Tooth #42: 51.7% were extruded, and 48.31% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.337; p>0.05).

Tooth #43: 31% were extruded, and 69% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.604; p>0.05).

Tooth #44: 31% were extruded, and 69% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.278; p>0.05).

Tooth #45: 34.5% were extruded, and 65.5% were intruded. There was no statistically significant difference in vertical measurement differences between teeth with extrusion and intrusion (p: 0.215; p>0.05).

Tooth #46: 27.6% were extruded, and 72.4% were intruded. The vertical measurement differences in teeth with intrusion were higher than in those with extrusion, but this difference was very close to significance and did not reach statistical significance (p: 0.057; p>0.05). (Table 7)

Table 8: Evaluation of interproximal reduction based on jaws

	Mandible (n=29)	**Maxilla (n=23)**	**Total (n=52)**	
IPR	**n (%)**	**n (%)**	**n (%)**	**p**
Yes	15 (%51,7)	5 (%21,7)	20 (%38,5)	0,055
No	14 (%48,3)	18 (%78,3)	32 (%61,5)	

Continuity (Yates) correction

The rate of IPR performed in the lower jaw (51.7%) was higher than in the upper jaw (21.7%), but this difference was close to significance and did not reach statistical significance (p: 0.055; p>0.05). The total IPR rate was 38.5%. The amount of IPR in the lower jaw ranged from 0.4 mm to 4.2 mm, with an average of 1.78±1.05 and a median of 1.6 mm. The amount of IPR in the upper jaw ranged from 0.2 mm to 1.8 mm, with an average of 0.64±0.67 and a median of 0.4 mm. The total IPR amount ranged from 0.2 mm to 4.2 mm, with an average of 1.50±1.08 and a median of 1.35 mm. (Table 8)

Table 9: Evaluating Interproximal Reduction Effects on Canine-Canine Discrepancy between IPR and Non-IPR Cases

Canine-canine discrepancy	**IPR**		
	Yes	**No**	
	Mean±SD (median)	**Mean±SD (median)**	**p**
Rotation (^{0})	1,09±0,77 (1,14)	1,18±0,64 (1,06)	0,554
Tip (^{0})	1,59±0,73 (1,68)	1,66±0,52 (1,71)	0,749
Torque (^{0})	0,93±0,72 (0,67)	0,85±0,55 (0,83)	0,940
Buccolingual (mm)	0,2±0,14 (0,15)	0,2±0,12 (0,17)	0,807
Vertical (mm)	0,46±0,45 (0,33)	0,29±0,17 (0,28)	0,182

Mann Whitney U Test

There was no statistically significant difference in the mean amount of rotation-related discrepancy between the canines in individuals who underwent IPR and those who did not (p: 0.554; p>0.05).

There was no statistically significant difference in the mean amount of tipping-related discrepancy between the canines in individuals who underwent IPR and those who did not (p: 0.749; p>0.05).

There was no statistically significant difference in the mean amount of torque-related discrepancy between the canines in individuals who underwent IPR and those who did not (p: 0.940; p>0.05).

There was no statistically significant difference in the mean amount of buccolingual discrepancy between the canines in individuals who underwent IPR and those who did not (p: 0.807; p>0.05).

There was no statistically significant difference in the mean amount of vertical discrepancy between the canines in individuals who underwent IPR and those who did not (p: 0.182; p>0.05). (Table 9)

Table 10: Correlation between the amount of Interproximal Reduction and Canine-Canine Discrepancy

Canine-canine discrepancy	IPR (mm)	
	r	**p**
Rotation (^{0})	-0,282	0,228
Tipping (^{0})	-0,189	0,424
Torque (^{0})	-0,201	0,395
Buccolingual (mm)	-0,106	0,656
Vertical (mm)	0,044	0,852

Spearman's rho correlation test

There was no statistically significant correlation between the amount of IPR and the amount of rotation between the canine-canine (p: 0.228; p>0.05).

There was no statistically significant correlation between the amount of IPR and the amount of tipping between the canine-canine (p: 0.424; p>0.05).

There was no statistically significant correlation between the amount of IPR and the amount of torque between the canine-canine (p: 0.395; p>0.05).

There was no statistically significant correlation between the amount of IPR and the amount of buccolingual discrepancy between the canine-canine (p: 0.656; p>0.05).

There was no statistically significant correlation between the amount of IPR and the amount of vertical discrepancy between the canine-canine (p: 0.852; p>0.05). (Table 10)

6. DISCUSSION

6.1. Evaluation of Material and Method

Evaluating the accuracy of tooth movements , thereby the predictability of the measured system, is a complex process. Regarding all the aspects of tooth movements, the result's reliability depends on many features.

In this study, we had to be dependent on the existing archive for the sample size since this is a retrospective study. The inclusion criteria was clustered from the existing cast models, 52 jaws from 36 patients. The existing studies who looked into the accuracy of tooth movement and treatment outcome in lingual orthodontics (121–123,145) had around the same sample size. The power analysis was also supportive of the sufficiency of our sample size.

In this retrospective study, the completely customized lingual appliance used to treat the patients was WIN appliance. The orthodontic archive had also Incognito appliance but the amount of cases were considerably unequal, therefore we chose to use a single brand to be more authentic in the measurement results.

The matching algorithm used in the software has a big influence on the accuracy of the results. Consequently, we removed all the elements that don't belong to the dental crowns before using the 'best fit' algorithm. The lingual retainers, buttons, gingival parts below the crown were thoroughly removed before the matching process. Due to the lack of stable structures in the upper or lower jaw that remain unchanged throughout the treatment process, variations can occur. However, in our study, the dental arch fits well overall, with only a few teeth exhibiting higher discrepancies. This suggests that the best-fit method remains practical.

In our study we utilized Geomagic Control X program. Recent studies (146–150) for 3D measurements in various fields of orthodontics, such as tooth movements in aligners, 3D printing,indirect bonding systems, skeletal evaluations, etc., have been also performed by Geomagic X which supports our predisposition of using this software.

According to the study conducted by Adel et al.(151) twenty pretreatment intraoral scans of maxillary patients undergoing clear aligner therapy were randomly chosen. Digital setups were created, both pretreatment scans and setups were converted to STL files and exported to Geomagic, OrthoAnalyzer-Model Set Compare, and Compare model registration software packages. The degree of movement for maxillary incisors and canines was calculated in six degrees of freedom. Geomagic exhibited excellent agreement overall, except for torque. In conclusion, measurements of maxillary central incisors had superior agreement, and Geomagic appeared to be the most accurate software among those studied. Hence, in anticipation of obtaining the most precise outcomes, we opted to employ this program, considering its potential for delivering optimal results in our study.

In this retrospective study, the initial models were taken from polyvinyl-siloxane material and the final models of the patients were collected with alginate material, not with intraoral 3D scanners. The digitalization of the cast models were made after the inclusion selection phase.

In a systematic review and meta-analysis conducted by Kong et al. (152) they compared the accuracy of digital and conventional full-arch impressions in vivo. Electronic and hand searches were conducted to find in vivo research comparing the linear or 3D precision of digital and traditional impressions. Twenty-two studies met the inclusion criteria, and 13 studies were included in the meta-analysis. There was no significant difference between digital and conventional impressions in the linear measurements of tooth width, anterior Bolton ratio, overall Bolton ratio, intercanine distance , and intermolar distance. This renders the reliability on the trueness and precision of digital and alginate full-arch impressions.

In recent years, the advent of three-dimensional (3D) scanning technology has revolutionized the field of dentistry, offering advanced tools for precise and efficient data acquisition. As the technology continues to evolve, 3D scanners play a pivotal role in enhancing the overall efficiency and precision of dental procedures. Many different types and brands are in use. In a systematic review by Jedlisnki et al. (153) stated that scanners of the same generation from different manufacturers have almost identical accuracy.

A study conducted by Lim et al. (154). They investigated the effect of the experience curve on changes in trueness when a patient's complete dental arch is scanned. The study included twenty dental hygienists with varying clinical experience, trained to use two intraoral scanner systems, Trios and iTero. They each conducted ten scans on an assigned patient. Precision was assessed by calculating mean deviations among superimposed combinations, while trueness was evaluated by comparing intraoral scans to impression scans. The goal was to gauge operator proficiency with the scanner systems. The study found that the Trios scanner exhibited greater mean precision compared to iTero (Trios: 52.30 mm; iTero: 60.46 mm; $p<0.01$). The iTero group demonstrated improved trueness with repeated experience ($p<0.05$), while the Trios group did not show significant improvement ($p>0.05$). In the iTero group, the length of clinical experience influenced trueness change due to repeated experience ($p<0.05$). Additionally, trueness results were better for the maxillary arch than the mandibular arch with repeated scanning in the iTero group. And in the study of Lee (155) the average differences between iTero and TRIOS (3Shape) were 0.057 mm at the maxilla and 0.069 mm at the mandible. It is stated that there was no statistically significant difference between two scanners in 3D direction. In another systematic review (156) they analyzed the accuracy of different scanners and concluded that different intraoral scanner systems appear to have the potential to provide an outcome of similar accuracy range.

Another study by Braian et al. (157) evaluated the trueness and precision of 5 different intraoral scanner devices; Emerald, Itero, TRIOS 3, Omnicam, and CS 3600. Two validation casts, one with teeth (dentate) and one without (edentulous), were created for a mandible with 5 cylindrical landmarks each. After being additively manufactured and measured with a coordinate measuring machine (CMM), the casts were scanned using different intraoral scanners, and the digital files were compared to the CMM data. Itero generally showed better trueness values compared to other scanners, especially in intercylindrical measurements on both edentulous and dentate casts. Since we already had iTero scanner in our clinic, we chose to go with it according to the results of these studies.

In our retrospective study, the lingual orthodontics archive was consisted of stone casts. Therefore, we digitalized the stone casts by 3D scanning them. In a study performed by Schieffer et al. (158) they evaluated the accuracy, consistency, reproducibility, and objectivity of measurements taken on stone casts from patients with mixed dentitions in comparison to measurements on three-dimensional (3D) digital models created from surface scans of the stone casts. They indicate that digital models, generated from surface scans of physical casts, may serve as a dependable alternative to stone casts for analyzing mixed dentitions. Measurements on virtual models demonstrate consistent intra- and interarch relationships, although influenced by operator experience. They conclude that additional research is necessary to evaluate the time demands and practicality of implementing this digital workflow in younger patients. In a prospective non-randomized clinical trial by Liczmanski et al. (159) Differences between digital models from alginate impressions and intraoral scans of orthodontic patients were investigated, total of 44 jaws were analyzed. They indicated the major errors are bubbles in fissures and marginal ridges as well as incomplete alginate flow and detachment from the tray. Alginate radicals create chemical bonds with enamel hydroxyapatite crystals, potentially causing imperfections in the impression. Consequently, this process may give rise to shape artifacts. But they concluded that even the intraoral scans exhibit greater detail and are less prone to errors, dimensional differences between intraoral scans and conventional alginate impressions in the mixed dentition are clinically tolerable.

Intraoral scanners can also transform traditional cast models into digital formats, enabling a more accurate fabrication of personalized braces, clear aligners, and orthodontic devices. In our study we had to digitalize the cast models. In a relevant study by Jabri et al. (160) to evaluate the accuracy of iTero scanning system in-vivo and ex-vivo on plaster casts, an electronic bibliography search was conducted by applying the Medline database. Publications until February 2020 were included. The terms that were included in the search were "Intra-oral digital scanning" combined with "intra-oral laser scanners," "Accuracy," "Reliability," "Digital models," "Orthodontics," "Extra-oral digital scanning," and "iTero scanner." Five hundred thirty-three articles were retrieved from bibliography search and among them, 93 full-text articles were reviewed. They stated that the current evaluation indicates the iTero digital intraoral scanning system exhibits superior accuracy and reliability in both intraoral and extraoral scanning, including performing linear measurements on digital dental models. iTero is recommended for constructing orthodontic appliances, as it demonstrates enhanced precision in its mechanical features, particularly when employed for extraoral scanning.

The process of choosing the measurement points were consulted with an engineer at the beginning of the study. We decided to use the labial side for the analysis since the lingual side may be compromised after the bonding/debonding procedures. Some other studies used the brackets for superimposition(121), iterative closest-point registration algorithm(119), or aligned the models to the plane in a manner such that the plane crossed every tooth at the approximate height of the bracket slots(122). Since we had the cast models of post-treatment without the brackets, we decided to use the 'best fit algorithm' first and arrange the cross-sections accordingly in every single measurement.

6.2. Assessment of the Results

The aim of this study was to compare the set-up and the result of the completely customized lingual systems. Rotational and translational movements of every tooth is assessed by analyzing tip, torque, rotation, mesiodistal movement, buccolingual movement and vertical movement. Superimpositioning the 3D models and sectioning in different planes, we achieved to measure the difference in all necessary angles.

All values showed that posterior teeth discrepancies were larger than anterior teeth but the vertical discrepancy between anterior and posterior teeth was not statistically significant. This result is convenient with the study of Grauer et al. (119) except the rotation. We find our result to be convenient since the slot shape is horizontal at the posterior, leading to a challenge in rotation control in holding the arch wire within the slot. The result may be thought as supported by torque and buccolingual measurements too since they are greater in posterior teeth due to the horizontal slot shape (161,162).

Measuring the torque values between the set-up and the result, both mandibular and maxillary teeth are found to be more retrusive according to the predicted movements. Only tooth number 16 is found to be more protrusive (%52,2 of all teeth number 16's) but it was found statistically not significant. Only statistically significant result was found for tooth number 43 with p value 0,045. This result may be a consequence of elastic chain usage. In lingual systems, applying brackets to the lingual surface results in a force closer to the center of resistance. While the use of elastic chains may lead to negative torque effects on anterior teeth, both negative torque and distal rotation are expected in posterior teeth (163).

After applying IPR between canine-canine, the minimal spaces were to be closed with an elastic chain. Treatment sequence involved aligning and leveling the teeth to establish the necessary interproximal contacts before proceeding with ideal abrasion. Following the reduction process, all the spaces were closed at the first two arch wires, which is right before the 0.018x0.025 NiTi arch wire. Thus, by the time this full slot arch wire is inserted, all gaps will have closed, and upon placement of this wire, full torque will be engaged, resulting with significant success in the outcomes in terms of inclination. Also applying IPR results with required space for teeth to rotate around their axes to their expected positions.

Since the slot system in our study is ‘ribbon wise, meaning vertical slot at the anterior between canine-canine and horizontal slot at the posterior, using vertical elastics are expected to decrease the torque discrepancy at the anterior teeth by pressing the wire into the slot.

In the study of Pauls et al.(122) they stated that teeth 16 and 41 have the smallest discrepancy but the second molars have the highest. Since we did not measure the second molars, we found teeth number 26 and 46 with the greatest discrepancy and teeth number 42 and 43 with the smallest torque discrepancy with a slight difference from lower incisor teeth thereby we can say it is coherent with our study.

In order to assess the mesiodistal translational discrepancy, the literature shows us that molars have the greatest difference between set-up and result(119). This supports our findings in our study with teeth number 16 and 46 with median of 0,31mm and 0,3mm respectively. The reason for this may be attributed to the significant differences observed primarily in the molars buccolingually, which could lead to inadequate width in the transverse direction, resulting in a more elongated U-shaped arch length. In addition, in our study, since we measured from the cross-section of planes, mesiodistal discrepancy amount could be affected by the tipping movement of the teeth.

In the study of Pauls et al. (122), mesiodistal translational movements were also measured in every tooth between second molars. We did not include the second molars in our study since they were debonded before the last arch wire in order to improve the interdigitation eliminating the occlusal pads when using vertical elastics. But coherent with the literature, we found teeth number 16 and 46 are more inaccurate according to the set-up with median of 0,31 and 0,3 respectively in mesiodistal measurements. It is also stated that tooth number 31 showed the smallest discrepancy in mesiodistal measurements, as we found tooth number 41 showed the smallest discrepancy at the same measurements.

Vertical measurements vary more between maxilla and mandible. Maxillary discrepancy was slightly greater than the mandibular discrepancy bu this was not statistically significant. Upper central incisors and canines are found to be more extruded considering the predicted tooth positions but this was statistically not significant. Contrarily, the lower central incisors and canines are found to be more intruded but this was also not significant. Intrusion of tooth number 33 is found statistically significant among other teeth (p:0,034). Upper lateral incisors were found intruded, but the premolars and first molars are found extruded without being statistically significant. Conversely lower lateral incisors were found extruded, but the premolars and first molars are found intruded at the lower jaw. Due to the rather small difference, these results were statistically insignificant.

In a study conducted by Pauls et al. (122) same movements with our study were analyzed using a different measurement method in the 3D analysis software. It is found that the torque movements were mostly found more retrusive in all the measurements and all the teeth were generally positioned more lingually especially in molars. They stated that most of the vertical movements were more infra-positioned. These results are coherent with our findings. They found that the central incisor movements are more accurate contrarily to lateral incisors. In our study also, lower lateral incisors are found more rotated than the central incisors but in other measurements, it is found vice versa. They found the greatest rotation discrepancy in upper left molars, which is coherent with our study which we found the same with tooth number 26 with a median of 2,73º. We also found the smallest rotation discrepancy in teeth number 41,21,22,12 respectively. Clinical studies have confirmed that a good and effective torque control can be achieved with lingual orthodontic treatments (62,164). That statement is matching with our results with great torque accuracy.

In the study of Grauer and Proffit (119), it is stated that the registration of set-up and final model depends on the average of the surface differences for the superimposition algorithm, therefore the greatest discrepancy would be expected at the terminal end of the surface, in our case, first molars. The arch wire operates like a cantilever at the terminal molars thus they are expected to be less efficient on vertical dimensions especially in use of intermaxillary elastics. They stated that this situation probably caused the second molars to exhibit the greatest discrepancy in planned and achieved tooth movements.

For the tipping measurements, Pauls et al.(122) stated that they found the greatest discrepancy in second molars, which we didn't include. In our study we found the greatest discrepancy in teeth number 45 and 36 with a 2,33º and 2,16º respectively. They stated the smallest discrepancy is found in tooth 14, contrarily we found the smallest discrepancy in teeth number 32 and 42. The reason for this result may be the usage of full slot arch wire after the leveling, aligning and closing of the spaces and also using the vertical elastics at the end at least 6 weeks, pressing the arch wire in the slot at full capacity.

In terms of the mesio-distal angulation of anterior teeth, a study by Fontinha et al.(165) revealed no variances between initial setups and post-treatment casts, despite the vertical slot orientation in the anterior segment, which could potentially affect angulation management. This result is coherent with our findings and other literature supports this statement (119,122).

Analyzing the buccolingual translational movements, maxillary discrepancy was found to be greater than mandibular discrepancy. Maxillary teeth were all positioned more lingually except the central incisors, but all were statistically not significant. Same results were found at the lower jaw with buccally positioned central incisors and lingually positioned lateral incisors, canines, premolars and first molars. These results were only significant for teeth number 41 (p:0,004), 42 (p:0,002) and 43 (p:0,023). A study conducted by Grauer and Proffit (119) also supports our founding with central incisors positioned more buccally and molars positioned more lingually. It is stated that molars are likely to be in a more constricted position but the incisors are positioned more protrusively. This could be due to the fact that dental arch expansion correlates with arch wire expansion up to a certain point; beyond this threshold, increased torsional stiffness of the wire becomes necessary but the last wire used in all the patients is 0.018x0.018 beta-titanium and its stiffness is smaller than stainless steel wire.

Khattab et al.(166) conducted previous research indicating that in lingual orthodontic treatments, the process of space closure is associated with a reduction in intermolar width, an expansion in intercanine width, and a significant reduction in anchorage loss specifically observed in the maxillary first molar. In our study, we didn't measure the intermolar width but we can say this result is relatively in line with our study by screening the buccolingual translational discrepancy measurements in first molars.

In the study of Pauls et al.(122), it is stated that lower central incisors have the smallest discrepancy, but the second molars show the highest discrepancy in buccolingual measurements. Coherent with our study, we found the greatest discrepancy in first molars and smallest discrepancy in teeth number 31,32,33 and 41,42,43 between 0,1 and 0,14mm. It is also stated in their study that all the translational discrepancies were mostly higher for second molars than for other teeth. It is the same in our study with first molars coherent with the literature (29,73,121,122) except the vertical measurements. We found that tooth number 23 showed the highest discrepancy by intrusion movement with a median of 0,37mm but this result was statistically not significant.

In a recent study (167), two fully customized lingual appliances (WIN and Incognito) and 2 labial bracket systems (Discovery classic and Discovery smart [Dentaurum, Ispringen, Germany]) were examined with NiTi wires of different cross-sections (0.012, 0.014, 0.016, and 0.016 × 0.022-in) and 3 tooth types (canine, lateral incisor, and second premolar). They stated that the premolar rotation showed greater discrepancy in lingual appliances. This may be the consequence of just measuring 3 types of tooth. If molar measurements were also added, the result may be different since it is the terminal tooth of the arch.

In a study conducted by Scisciola et al.(58) they investigated the accuracy of torque, tip and rotation and linear intra-arch movements applied by passive self-ligating lingual straight-wire appliance (ALIAS, Ormco, Orange, CA). They stated that accuracy in torque and linear movements was notably high in the anterior sectors but diminished in the posterior sectors. Both tip and rotation movements demonstrated high accuracy levels in both the anterior and posterior sectors. Another study (168) the accuracy of same movements was measured in STb brackets and found a slightly greater accuracy for angular movements. Coherent with our study, in terms of tip, rotation and torque movements, the anterior region exhibited better accuracy, while we observed more discrepancies in the posterior region. Linear movements showed smaller accuracy at posterior area as expected and coherent with the current literature. Due to these factors, it is advisable to include a preliminary expansion phase in cases necessitating transverse arch expansion, or to overcorrect the transverse dimension in the final arch wires during planning.

The existence of the vertical slot's lingual wall guarantees that the arch wire stays securely within the slot while correcting tooth rotations or retracting the anterior segment, minimizing torque loss and thereby enhancing the three-dimensional control of the teeth.

In our study the crowding at the anterior (canine-canine) did not differ significantly in any direction or movement between IPR added arches and non-IPR arches. This was also our prediction since the IPR was done considering the Bolton discrepancy and strictly according to the company's instructions, gauging with the IPR ruler.

In a study conducted by Zhang et al. (125) they investigated crown and root movements in clear aligners. They found the mean discrepancy of maxillary crown positions was 0,376 ± 0,041mm, while that of the mandibular anterior teeth was 0.398 ± 0.037 mm. They stated the clear aligners mostly moved anterior teeth by tilting motion. We can not compare this to our study since the method is considerably different but the amount of movements is close to our findings.

In a study conducted by Grünheid et al. (169), they treated 30 patients with Invisalign. After superimposition of final and set-up models with best fit algorithm, they measured rotational and translational movements in every tooth. They found central incisors positioned more buccally, extruded and retrusive, same as in our study. They also found both upper and lower molars protruded, contrarily in our study, we found them more retruded. This may be because the aligner material was insufficient to apply transversal force to the molars for expansion of the arch so it applied buccal tilting force on the molars. In both studies, the premolar and molars are positioned more lingually.

7. LIMITATIONS

Measuring tooth movements poses a significant challenge in orthodontic research due to the intricate interplay between various types of movements, such as tipping, rotation, and bodily translation. These movements are often intertwined, making it difficult to discern their individual contributions to overall tooth displacement accurately. As a result, researchers have had to devise sophisticated and multifaceted methodologies that can account for the complex interactions between different types of tooth movements. These methodologies aim to provide a comprehensive understanding of how teeth respond to orthodontic forces and interventions, ultimately enhancing the precision and reliability of orthodontic treatment outcomes.

The main limitation of our study is it's retrospective nature. To obtain more reliable results, prospective studies with increased number of participants should be considered in future studies. Controlling every ligation, elastic usage and appliance addition would give us a better precision of measurements. Another limitation is the lack of evaluation of intermaxillary relationships and occlusion. Therefore, the effects of appliances such as intermaxillary elastics, Herbst, or Forsus appliances could not be assessed.

In order to determine the long axis of the tooth, the roots and apex should be available for the assessment but since not all the patients had the CBCT, it was not included.. Further studies may be conducted according to 3D imaging with CBCT combination.

8. CONCLUSION

To summarize the results; for torque, tip, rotation, mesiodistal translation and vertical translation, the discrepancy wasn’t statistically significant for maxilla and mandible. Thereby, planned set-up and the treatment result are highly compatible. Only the buccolingual discrepancy was statistically significant with a greater difference in maxilla.

All the measurements were greater with a statistical significance in posterior area except the vertical translational discrepancy, with anterior region greater than posterior region but it’s statistically not significant.

Torque movements were measured retruded in the results with the only statistically significant difference in tooth number 43. Vertically, only statistically difference was measured in an intruded movement of tooth number 33. Buccolingual translational movements were statistically significant in teeth number 41,42,43. The lower incisors were positioned more buccally but the canines were positioned more lingually.

Our study's results are consistent with the literature, and the setup and result appear to be highly compatible with this system. To further clarify this method, studies incorporating intermaxillary relationships and a larger participant pool are needed. CBCT records should be used for better accuracy in measurements.

With this study, we conclude that the results are predictable and precise if all the treatment protocols are conducted correctly and in order. This provides orthodontists a great foresight into the results being coherent with planned set-up.

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10. APPENDICES

10.1. Ethical Approval

T.C.
YEDİTEPE ÜNİVERSİTESİ REKTÖRLÜĞÜ
Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu

Sayı : E.83321821-805.02.03-301
Konu : Etik Kurul Karar Yazısı

Sayın Dr. Öğr. Üyesi Can ARSLAN

Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kuruluna etik onay için başvuru yapılmış olan araştırma önerisinin başlığı, araştırmacılar, başvuru numarası, sunulan belgeler ve toplantı bilgileri aşağıda yer almaktadır. İlgili araştırma önerisi, etik kurulumuz üyeleri tarafından değerlendirilmiş olup, etik ve bilimsel açıdan **UYGUN *** olduğuna karar verilmiştir.

***Açıklama bölümünde belirtilmiş olan maddelerin yerine getirilmesi koşuluyla kabulü uygundur.**

Araştırma Başlığı:	Measuring the Predictability of Target Set-up in Customized Lingual Orthodontic Treatment
Araştırmacılar:	Pelin Babayiğit, Dr.Ögr.Üyesi Can Arslan
Başvuru Numarası:	202311Y0496

TOPLANTI BİLGİLERİ			
Toplantı Tarihi:	08.12.2023	**Toplantı Yeri:**	Çevirim içi (Google Meet)

***AÇIKLAMA**

- Araştırma başvurusu Türkçe belge ile yapılmış olup başvuru başlığı İngilizce yazılmıştır.
- Araştırma sorusu hakkında bilgi (bilinenler/bilinmeyenler) yeterli şekilde açıklanmamıştır
- Konu ve kavramlar açıklanmamıştır. Kaynaklar ile desteklenmemiştir.
- Araştırma türünün probleme uygun olup olmadığı açıklanmamıştır.
- Bağımlı-bağımsız değişkenler doğru yazılmamıştır.
- Evren açıklaması uygun değildir.
- Örnekleme yöntemi belirtilmemiştir.
- Verilerin toplanmış olduğu yazılmıştır. İş planlaması Etik kurul öncesi tamamlanmış görülmektedir, zaman çizelgesinin yeniden düzenlenmesi gereklidir.
- Diş Hekimliği Fakültesi Bilim Kurulu onayı alınıp alınmadığı anlaşılamamıştır.

SUNULAN BELGELER

Bu belge, güvenli elektronik imza ile imzalanmıştır.
Belge Doğrulama Adresi : http://belgedogrulama.yeditepe.edu.tr/bg.aspx?id=70F7063A-219E-47D5-8B13-AC25051CB57E

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Bilgi İçin: Sevgi BAYRAKTAR
Unvan: Uzman Yardımcısı
Telefon No: (0216) 578 00 00 / 6347

Islak imzalı başvuru dosyası, CD veya USB belleğe kaydedilmiş başvuru dosyası ve elektronik başvuru
Araştırma başlığı ve araştırmacıların isimleri
Başvuru dilekçesi
Başvuru formu
Araştırmanın;
Niteliği
Önemi ve özgün değeri
Amaç ve hedefleri
Yöntemi
Yönetimi
Yaygın etkisi
Araştırma bütçesi (Mevcutsa)
Süresi ve uygunluğu (Zaman cetveli)
Kaynakları
Bilgilendirilmiş Gönüllü Olur Formu (yapılan araştırmaya özel olarak hazırlanmış)
Taahhütname-1 Araştırmanın yapılacağı kurumdan izin alma sorumluluğunun araştırmacılara ait olduğuna dair taahhüt
Taahhütname-2 Dünya Tıp Birliği Helsinki Bildirgesinin son versiyonunun ve Sağlık Bakanlığı'nın ilgili tüm kılavuzlarının okunmasına dair taahhüt
Taahhütname-3 Daha önce yapılmış etik kurul başvuruları mevcut olup olmadığına dair taahhüt
Taahhütname-4 Araştırma sırasında araştırma bütçesinde yer almayan ve gönüllünün kendisine veya Sosyal Güvenlik Kurumuna ek yük getirecek hiçbir işlem uygulanmayacağına dair taahhüt
Taahhütname-5 COVID-19 hastalarında tedavi yaklaşımları ve bilimsel araştırmalar genelgesi okunmasına dair taahhüt
Taahhütname-6 Millî Eğitim Bakanlığı Araştırma Uygulama İzinleri konulu yazının okunmasına dair taahhüt
Araştırmacıların her birisine ait özgeçmiş formu
Ek belgeler (Varsa kullanılan ölçek)

Prof. Dr. Didem ÖZDEMİR ÖZENEN Başkan	Doç. Dr. Gökhan ERTAŞ Başkan Yardımcısı	Prof. Dr. Elif SUNGURTEKİN EKÇİ Raportör

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Dr. Öğr. Üyesi Elif Çiğdem KELEŞ Üye	Dr. Öğr. Üyesi Sevim ŞEN OLGAY Üye

11. CURRICULUM VITAE

Kişisel Bilgiler

Adı	Pelin	**Soyadı**	Babayiğit

Öğrenim Durumu

Derece	Alan	Mezun Olduğu Kurumun Adı	Mezuniyet Yılı
Doktora	Ortodonti	**T.C. Yeditepe Üniversitesi**	2024
Lisansüstü	Diş Hekimliği	**İstanbul Yeni Yüzyıl Üniversitesi**	2018
Lise	-	**Özel Notre Dame de Sion Fransız Lisesi**	2013

Başarılmış birden fazla sınav varsa(KPDS, ÜDS, TOEFL; IELTS vs), tüm sonuçlar yazılmalıdır

Bildiği Yabancı Dilleri	**Yabancı Dil Sınav Notu (#)**
İngilizce	IELTS: 7 , YÖKDİL:97
Franzısca	DELF B2

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	**Kurum**	**Süre (Yıl - Yıl)**
Diş Hekimi	Acıbadem Maslak Hastanesi	2 (2022-2024)
Diş Hekimi	Acıbadem International Hastanesi	3 (2021-2024)
Diş Hekimi	Razmik Ramiz Nahcivan Ortodonti Kliniği	1 (2018-2019)

Görev Aldığı Projeler/Sertifikaları/Ödülleri

Lingual Ortodonti Derneği Sempozyumu Vaka Sunumu Birinciliği
Invisalign Sertifikası
WIN Lingual Ortodonti Sistemleri Sertifikası