T.C.
YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF ORTHODONTICS

EXAMINATION OF MICROLEAKAGE ON DIFFERENT ORTHODONTIC RETAINERS UNDER SIMULATED GASTROESOPHAGEAL REFLUX DISEASE (GERD) – AN IN-VITRO STUDY

DOCTOR OF PHILOSOPHY THESIS

SİMAY YILMAZ, DDS

İstanbul-2023

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İstanbul-2023

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Institute : Yeditepe University Institute of Health Sciences
Programme : Doctoral Program in Orthodontics
Title of the Thesis : Examination of microleakage on different orthodontic retainers under simulated gastroesophageal reflux disease (GERD) – An in-vitro study

Owner of the Thesis : Simay Yılmaz

Examination Date. : 12.12.2023

This study have approved as a Master/Doctorate Thesis in regard to content and quality by the Jury.

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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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Director of Institute of Health Sciences

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.

SİMAY YILMAZ

ACKNOWLEDGEMENTS

I am deeply grateful to Prof. Dr. Didem Nalbantgil, my thesis advisor, who has tirelessly contributed and never hesitated to provide assistance during my doctoral education. I always felt her support, and I consider her as a role model for her medical expertise, communication with patients, practical skills, and for her conflict resolution skills. I am proud to be her student, and I will always be grateful for her positive attitude, smile, and passion for teaching throughout my professional life.

I extend my sincere appreciation to Prof. Dr. Derya Çakan, the head of the department, for sharing boundless knowledge, individually guiding us with patience every Tuesday, and being a shining example of discipline and adherence to rules. I believe she embodies the essence of academia, and I will cherish our New Year karaoke parties together.

I would like to express my gratitude to Assoc. Prof. Dr. Murat Tozlu and Prof. Dr. Feyza Eraydın, who continuously encouraged us to use practical approaches and to innovate. I appreciate Assoc. Prof. Dr. Burcu Nur Yılmaz for being a mentor who, when necessary, was strict and, at other times, was an older sister whose door I could knock on for any need. I am thankful to Dr. Gonca Yıldırım, whose vibrant personality I believe brought a unique atmosphere to Yeditepe.

To the valuable professors I met in the later years of my doctoral education—Assoc. Prof. Dr. Seden Akan, Dr. Merve Nur Eğlenen, Dr. Mustafa Dedeoğlu, and Dr. Can Arslan—I express my gratitude for their enjoyable collaboration and continuous support. I would like to express my honor for the participation of Prof. Dr. Çağla Şar in my doctoral thesis jury and my sincere gratitude to her for not declining our invitation. Special thanks to my mentor, Dr. Gülengül Duman, for her assistance in preparing the corrections for my thesis, and to Prof. Dr. Meriç Karapınar Kazandağ for her support during the microscopic examination of my samples.

I consider myself fortunate to have worked closely with Prof. Dr. Ahmet Keleş, whose practical intelligence and guidance greatly contributed to my development. I

deeply appreciate his patience in explaining each case's initial photographs and sharing his extensive knowledge with me.

I would also like to express my thanks to Dr. Didem Aktan Meriç, who touched my life beautifully, deserves my gratitude for being a unique mentor, friend, and sister. She has illuminated my path with her experience, always trusting and encouraging me in every situation. Thanks to her, I find pleasure in improving myself on different aspects of orthodontics. Also, Dr. Uğur Meriç, who has always been like a brother to me in every aspect has contributed significantly to this journey.

I awould like to extend my heartfelt thanks to my doctoral companion, Kaan Emekli, with whom I've shared both successes and failures since the beginning of my doctoral education, and from whom I've gained valuable insights on this journey.
I extend my gratitude to Dr. Mustafa Özcan, a consistent guide throughout my journey, Dr. Elif Akın Özgünler, who holds a special place in my heart, Dr. Tarek Abied, Dr. Beyza Yıldız, and Dr. Ünalp Can Mustu, from whom I've not only gained knowledge but also shared enjoyable moments. I am also thankful to Helin Nisa Biçici, Pelin Babayiğit, and Eylül Öğüt, with whom I've shared many enjoyable moments. Throughout my doctoral education, the friendship with this group brought immense joy to every moment, and they will always hold a special place in my memories related to Yeditepe Orthodontics.

In both my undergraduate and doctoral studies, I am thankful for the unwavering presence of my dear friends with whom I have taken great pleasure in walking the educational path at Yeditepe. To Dr. Begüm Varol, Dr. Dila Dağaşan, Dr. Deniz Balcı, Dr. Dilek Düzenli, Dr. Yağmur Yıldırım, Dr. Kerim Aktaş, Dr. Buğra Aydemir, Dr. Mert Gerek, my roommate Dr. Bilge Erdoğan, Dr. Alperen Öz, Dr. Hatice Çetinkuş, and Dr. Ayşe Çelik, each of whom has become a highly skilled professional in their field, I am grateful for the beautiful memories we have created together.

I am also grateful to my friends Dr. Meltem Salt, Cihan Önalan, Aslı Şahin and Melis Özel who have supported me closely, even though they are not dentists.

I cannot imagine how this process would have been completed without Dr. Emre Aktan, who supports me, motivates me, who is always by my side, and in whom I have unwavering trust in professional knowledge, ethics, and ability, brings me extreme joy in every aspect of life.

Throughout my educational journey, my family also has been by my side and I am thankful for them. My grandmother, who brought me joy every morning with her phone calls, and my dear grandfather and grandmother, who desired to witness this moment the most… Even though they are not physically here, I believe they're are watching me from somewhere.

Finally, my greatest blessings in life, my angel, my dear mother Figen Yılmaz, who has always believed in me and made me feel her love and support throughout my life; my rock, my refuge when lost in the chaos of life, my dear father İlyas Yılmaz; and my loving sister Elif Su Yılmaz, who is always there for me. I express many thanks to each one of them for their tremendous efforts and sacrifices that have brought me to where I am today.

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LIST OF SYMBOLS AND ABBREVIATIONS

HAp : Hydroxyapatite

μm : Micrometer

mm : Milimeter

nm : Nanometer

% : Percent

MPa : Megapascal

SEP : Self-etching primer

SEA : Self-etching adhesive

LED : Light emitting diode

WSL : White spot lesion

CT : Computed tomography

GER : Gastroesophageal Reflux

GERD : Gastroesophageal Reflux Disease

GIS : Gastro-intestinal System

CR : Centric Relation

MI : Maximum Intercuspidation

TMJ : Temporomandibular Joint

SS : Stainless Steel

ABSTRACT

Yılmaz, S. (2023) Examination of microleakage on different orthodontic retainers under simulated gastroesophageal reflux disease (GERD) – An in-vitro study. Yeditepe University, Institute of Health Sciences, Department of Orthodontics PhD Thesis, İstanbul.

The aim of this study is to evaluate the microleakage on two different orthodontic retainers under simulated gastroesophageal reflux disease. While bonding the retainers, the impact of two different bonding materials with the effect of the previous air abrasion of the enamel to the microleakage will also be observed. 144 extracted bovine incisors were divided randomly into sixteen groups, each group containing 9 samples. Eight of these groups were preconditioned with air abrasion. Two different adhesives (37% phosphoric acid + 3M Transbond XT primer + 3M Transbond LR adhesive and 37% phosphoric acid + Transbond XT primer + 3M Flowable Composite) were used to bond two different types of retainers (braided retainer wire of .10×.028-inch 6" length and ss multi-strand wire with co-ax straight length 0215 14"). Elipar S10 curing light was used to polymerize these adhesives. After the bonding procedure, the speciments were subjected to 2 different immersion regimens. While the eight of the groups were immersed in simulated gastric solution of pH 1.5, the other half of the groups were immersed in the artificial saliva with pH 7. Immersion regimes were carefully carried out for 8 days; each immersion lasting for five minutes. The regime was distributed over a 12-hour period. At the end of immersion period, all the tooth surfaces except 1 mm wide zone around the margins of the bonded retainer were painted with nail varnish. After the nail varnishing process is done to the all samples, they were immersed in 0.5% basic fuchsine solution for 24 hours at room temperature. Afterwards the specimens were sectioned parallel to the lingual retainer wire with a dental diamond saw (Meisinger, Neuss, Germany) and evaluated under microscope (20x magnification) at enamel adhesive interfaces from mesial and distal margins. Microleakage was observed in all groups. There was no significant difference between microleakage scores of mesial and distal margins ($p > 0.05$). There was no statistically significant difference between two different orthodontic retainer types microleakage scores in any of the groups at the $p<0.05$ significance level. Among all groups, the microleakage score of the group immersed in the solution of pH 1.5 showed statistically significantly higher result than the group which is exposed to a solution of pH 7. The acidity of the pH solution increased the microleakage score. The microleakage

score of the group which has not gone under a previous air abrasion of the enamel showed statistically significantly higher result than the group which has undergone a previous air abrasion of the enamel. Among the adhesive systems which were used, it was found that all of the groups which have undergone to an immersion to pH 1.5 have not shown any statistically significant result with microleakage. When the speciments were immersed in the solution of pH 7, the adhesive systems showed statistically significant results with their microleakage scores. The flowable composite exposed higher microleakage score than the Transbond LR composite.

Keywords: microleakage, retainers, air abrasion, adhesives, GERD

ÖZET

Yılmaz, S. (2023). Gastroözofageal Reflü Hastalığı (GÖRH) Taklit Edilmiş Ortamda Ortodontik Retainerlardaki Mikrosızıntının İncelenmesi – *İn-Vitro* Çalışma. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Ortodonti ABD., Doktora Tezi, İstanbul.

Bu çalışmanın amacı taklit edilmiş gastroözofageal reflü hastalığı altında iki farklı ortodontik retainer teli üzerindeki mikrosızıntıyı değerlendirmektir. Retainerlar yapıştırılırken iki farklı adesivin etkisi ve minenin adezyon öncesi yüzey hazırlığının mikrosızıntıya etkisi de gözlemlenecektir. 144 çekilmiş sığır dişi gelişigüzel şekilde on altı gruba ayrılmıştır. Bu gruplarda sekizine kumlama uygulanmıştır. Retainerları mine yüzeyine yapıştırmak için iki farklı adeziv kullanılmıştır: %37'lik fosforik asitle pürüzlendirme + Transbond XT Primer + 3M Transbond LR ve %37'lik fosforik asitle pürüzlendirme + Transbond XT Primer + 3M Akışkan kompozit. Adeziv polimerizasyonu için Elipar S10 Curing Light kullanılmıştır. Yapıştırma işlemi sonrasında örnekler 2 farklı solüsyona maruz bırakılmıştır. Solüsyonların pH çözeltileri; şiddetli gastrik regürjitasyonu simüle eden pH 1,5 ve pH 7 ile yapay tükürük ortamını taklit etmektedir. Grupların yarısı pH 1.5'luk solüsyona, diğer yarısı da pH 7'lik solüsyona maruz bırakılmış ve bu işlem her bekletme 5 dakika olacak şekilde 12 saatlik periodlarda 8 gün boyunca tekrarlanmıştır. İşlemler devamında retainer yapıstırılan bölgelerin 1 mm dısından itibaren tüm diş yüzeyleri oje ile boyanmış ve örnekler %0.5'lik bazik fuksin solüsyonuna maruz bırakılmıstır. Örnekler daha sonrasında lingual retainera parallel olacak şekilde elmas disk testere (Meisinger, Neuss, Germany) ile ikiye ayrılmış ve sonrasında mikroskop ile 20× büyütme altında mezial ve distal sınırlardan incelenmiştir. İki farklı ortodontik retainer telinin mikrosızıntı skorları arasında istatistiksel olarak anlamlı bir fark bulunmamıştır ($p<0.05$). Tüm gruplarda pH 1.5'luk solüsyonlara batırılan örnekler pH 7'lik solüsyona maruz bırakılan örneklerden istatistiksel olarak anlamlı derecede daha yüksek mikrosızıntı skoru göstermiştir.

Bonding işlemi öncesi kumlama ile mine pürüzlendirmesine maruz bırakılan örneklerde, kumlama yapılmayan örneklere göre istatistiksel olarak anlamlı derecede daha az mikrosızıntı skoru izlenmiştir. Kullanılan adeziv sistemler arasında, pH 1.5'da istatistiksel olarak anlamlı bir fark bulunamasada, pH 7'de akışkan kompozit ile mine sınırında, Transbond LR'ye göre istatistiksel olarak anlamı bir fark sergileyecek oranda daha fazla

mikrosızıntı tespit edilmiştir.

Anahtar Kelimeler: mikrosızıntı, retainer, kumlama, adezivler, gastroözofageal reflü hastalığı

1. INTRODUCTION and PURPOSE

In orthodontics the retention is as important as the active orthodontic treatment process. Most of the patients come up with the question " Will my teeth deteriorate after my treatment is completed?" or "Will I have caries under my brackets after the treatment is done ?". To minimize these problems, a reliable bonding procedure of the retainer and an experience of least microleakage is important. Establishing a consistent attachment between an orthodontic retainer and the enamel is crucial for achieving an efficient and successful orthodontic procedure. Within time different retainer types and different adhesives were introduced in the orthodontic literature for bonding a retainer.

Gastroesophageal reflux disease (GERD) is a common problem that affects about 1 in every 4-5 individuals. The illness prevalence in Turkey ranges from 19 to 25%[1,2]. GERD is caused by temporary relaxation of the lower esophageal sphincter, resulting in the escape of stomach contents into the esophagus and eventually reaching the oral cavity[3]. Due to the stomach content having a pH below 1, the continuous acid exposure may cause harm to the soft and hard tissues of the mouth cavity by creating a lasting acidic environment[4]. Recent investigations have shown that people with GERD have higher levels of pepsin content in their saliva compared to persons who are in good health. Thus, the identification of pepsin in the esophagus and proximal region is considered a reliable biomarker for diagnosing GERD[5]. Considering the impact of GERD on the mouth, research clearly indicates that both the soft and hard tissues, as well as the dental materials used, might be affected.

In addition to many adhesive systems that have diverse useful properties, there are also alternative enamel preparation techniques such as air abrasion. The air abrasion method utilizes high-speed delivery of highly focussed aluminum oxide particles, forced by air pressure[6]. This method is used to improve the roughness of non-enamel surfaces such as metal and porcelain. Additionally, it is directly applied on enamel surfaces to remove impurities and simultaneously improve the roughness of the enamel[7].

The purpose of this in vitro study is to evaluate the microleakage scores on different orthodontic retainers and different adhesives with or without previous air abrasion under oral environments with different pH values.

The null hypothesis of this study is that; there is no significant difference between the microleakage amounts under the different retainer types bonded with different adhesive systems, with or without previous air abrasion technique under different pH values of oral environment.

2. LITERATURE REVIEW

2.1. Adhesion and Dentistry

In dentistry, adhesion is the bonding of two different surfaces to each other with an adhesive material. Adhesion is typically accomplished using a viscous substance that solidifies and joins two surfaces together while transmitting forces between them. Adhesion can occur through three distinct mechanisms: physical bonds, chemical bonds, and mechanical bonds[8].

In dentistry, adhesion plays a crucial role as resin-based dental materials adhere to enamel and dentin through four different mechanisms: mechanical adhesion, adsorption adhesion, diffusion, and a combination of these mechanisms. Firstly, the penetration of resin tags into the enamel and dentin represents a form of mechanical adhesion. Secondly, the chemical attachment of resin-based dental materials to the inorganic tooth structure or organic matrix demonstrates adsorption adhesion. The third mechanism involves diffusion adhesion, where substances precipitated on the tooth surface chemically or mechanically connect with resin monomers. Finally, a combination of these three mechanisms exists between resin-based materials and dental tissues[9]. To achieve effective adhesion, it is crucial to ensure close contact between the adhesive and enamel. The surface energy of the bonding surface must exceed the adhesive's surface tension.

The adhesion in orthodontics is important regarding the cementation of the fixed orthodontic devices to the enamel surface. Success of the cementation depends on the adhesive, enamel surface, occlusal forces with biting, pH, moisture and temperature differences. The type, duration and the concentration of the acid used with enamel etching are also important factors.

In particular, failure of the adhesion of the lingual retainer may lead to undesirable results such as increasing the cost of treatment and affecting patient comfort by requiring a second treatment. Therefore, adhesion directly affects the success of orthodontic treatment[10].

2.1.1. Mechanism of Adhesion

Dental adhesives are solutions of resin monomers that facilitate the interaction between dental tissues and composite resins[11]. To achieve a robust bond between teeth and the composite material, it is essential for adhesives to contain resin monomers. These adhesive resin monomers consist of hydrophilic and hydrophobic groups. The hydrophilic groups ensure proper wetting of dental tissues, while the hydrophobic groups enable interaction and copolymerization with the restorative material[12]. The resin matrix, which is cured within the adhesive, serves as a supportive mechanism that enhances the structural integrity, leading to improved physical and mechanical properties. Among the components of dental adhesives, the monomers play the most crucial role[13].

The adhesion properties of dental adhesives rely on two layers: the first layer involves the binding of the adhesive to the enamel, while the second layer pertains to the binding of the adhesive to the lining composite. The adhesion between the adhesive and the composite occurs through a process called copolymerization, which involves the residual double bonds within the oxygen inhibition layer.

When it comes to bonding with enamel, micromechanical adhesion is the primary mechanism at play[14]. This adhesion is achieved through two main processes: diffusion and capillarity. By etching the enamel, microscopic porosities are created, which increase the surface area and wettability. This enhances the penetration of the adhesive into the enamel, resulting in the formation of resin tags and the retention of the adhesive through micromechanical means[15–18]. During the curing process, the resin monomers replace the inorganic tooth material and become locked within the retention areas.[19] This microscopic interlocking of the adhesive resin with the etched enamel pits and the binding of the adhesive resin to exposed collagen fibers in dentin is referred to as hybridization[20].

The relationship between dental adhesives and dental tissues has been a subject of interest for researchers in various fields such as preventive and restorative dentistry and orthodontics over the years. When examining dental materials and their bonding to dental tissues, researchers typically prefer to use specimens of human teeth as the results are more clinically relevant. However, obtaining an adequate amount of human teeth has posed challenges. With advancements in preventive and restorative dentistry, it has

become harder to obtain a sufficient supply of human teeth, and many extracted teeth may have significant caries or defects[21,22]. Additionally, there are concerns regarding the risk of infection when working with human tissue samples, as well as ethical considerations in extracting non-carious teeth[23].

To overcome these challenges, researchers have turned to alternative mammalian substrates such as bovine, swine, or equine teeth. Mammalian teeth share similarities in terms of histology and morphology, making them viable substitutes for human teeth in studies[24–26]. Among these alternatives, bovine teeth have become a preferred choice due to their abundant availability, uniform composition, and the presence of large, defect-free flat surfaces, which makes them particularly suitable for adhesion studies[27,28].

Based on Yassen et al.'s[29] literature review, the chemical composition of human and bovine enamel exhibits only slight differences, and their physical properties are similar. Bovine enamel has proven to be a successful alternative to human enamel in bond strength studies, even though the bond to bovine teeth's surface is reported to be 21% to 44% weaker than that of human enamel[30].

However, there are conflicting results regarding the bond strength differences between human and bovine enamel[31]. Some studies suggest that there are no significant differences in bond strength between the two, adding to the complexity of the findings. When it comes to microleakage, some researchers have observed higher microleakage percentages in bovine teeth compared to human teeth[32–34]. Conversely, other studies have found no significant differences in microleakage scores between human and bovine enamel[29,35,36].

In conclusion, while bovine enamel may not behave identically to human enamel, it is widely accepted as a useful substitute in adhesion studies. Its similarities in chemical composition and physical properties make it a valuable alternative, though researchers need to consider the variations in bond strength and microleakage findings between the two substrates.

2.2. Classification of Dental Adhesive Systems

The adhesive systems have seen several advancements and diverse application methods from the 1950s to the present. Understanding the elements of the bonding systems is necessary before being able to completely know the operations and categorize the dental adhesive systems. Etchants, primers, and bonding resins are the three main elements of bonding systems. First of all an essential component of the complete etch adhesive systems is the etchant, which is typically 37% phosphoric acid. The acid etching technique prepares the enamel and dentin for the priming. Crystals on the enamel are broken down during this process, which also makes it easier for the adhesive resin to penetrate and create mechanical interlocking[37,38]. Secondly, the primer's hydrophilic monomers, ensures flowability and penetration. At the final , a thin coating of resin-based bonding agent is placed between the composite and the tooth surface that has been prepared. By acting as a connector between the hydrophilic primer and the hydrophobic composite, it creates the binding between the enamel and the composite resin[39].

Different categorization systems for dental adhesives have been created throughout time, and they are based on clinical practices and generational advancement. There are four classes based on clinical steps (Figure 2.1): [39]

1. Three steps adhesive systems: In this system the etchant, primer and the bond are in different bottles. This method presents the greatest bond strengths and is the most sensitive when used in a clinic[40].
2. Two steps (1) adhesive systems: There are two bottles; one contains an etchant, and the other combines a primer and a bonding agent[39].
3. Two steps (2) adhesive systems: There are two bottles; the etchant and the primer is combined together as a first step and afterwards the bonding agent is applied seperately[39].
4. One step adhesive systems: They just have one bottle of bonding and a self-etching primer. This method is simple to use in the clinic[39].

Regarding the historical development there are eight generations (Figure 2.1):

First Generation: This generation was first introduced by Buonocore in1956[41]. With this technique, the bonding agent adheres to HAp with an ionic bond and adheres

to the collagen with a covalent bond. Since water weakens these bonds, very low bond strengths and poor clinical results were obtained[42].

Second Generation: This generationconnects the calcium and phosphate groups with ionic bond but they breake rapidly in water and this generation is not used any more[42].

Third Generation: By the late 1970s and early 1980s, this generation had been launched, with the goal of allowing the resin to permeate the dentin tubules by etching the dentin and changing the smear layer[42].

Fourth Generation: This generation was launched in the 1980s and 1990s and guarantees that the smear layer is completely removed. This generation is a clinical illustration of a three-step adhesive method. Etchant, priming, and bonding are all in their own bottles[42].

Fifth Generation: Since the 1990s, there has been a concerted effort to streamline and minimize the procedural complexities associated with adhesive systems. The current generation serves as a manifestation of etch and rinse two-step systems. The initial stage involves etching, followed by the subsequent application of a single bottle comprising the primer and bonding adhesive[43].

Sixth Generation: The sixth generation was introduced during the late 1990s and early 2000s. The primary objective of this generation was to eliminate the etching process. Within the current era, there exist two distinct containers. The initial sample incorporates self-etching primers, while the subsequent sample incorporates the adhesive component. It is recommended that the blending of these two fluids occur immediately prior to their application onto dental surfaces[42].

Seventh Generation: This particular generation is commonly referred to as a self-etching system utilizing a single bottle. All the requisite bonding components are contained within a single vessel, obviating the need for any mixing process. The bonding procedure has been significantly simplified with the advent of this generation[43].

Eighth Generation: The year 2010 saw the introduction of eighth generation bonding agents, which incorporated newly added nanofillers to improve the penetration

of resin monomers and achieve a more substantial hybrid layer. Consequently, upgraded mechanical properties were attained[44].

The most recent advancement in adhesive technologies refers to universal adhesive systems, which possess the capability to be utilized in conjunction with the acid etching process or as a self-etching adhesive. Universal adhesives have been developed to enable the utilization of a single adhesive across various application methods[45].

Figure 2.1 Classification of adhesive systems [39]

2.2.1. Etch and Rinse Adhesive Systems

Etch and rinse adhesive systems, regarded as the most ancient among bonding systems, involves an etching stage that necessitates subsequent rinsing following the etching procedure. The primary objective of the etching process is to increase the surface area. Etching can result in various surface modifications, such as chemical alterations in the organic matrix and decalcification of the inorganic component. However, the primary significance lies in the enhanced suitability of the enamel for adhesive bonding[46]. The

rinsing process following etching effectively eliminates the smear layer and facilitates the removal of smear plugs. Consequently, the enamel surface undergoes preparation to facilitate adhesive bonding.

Since Buonocore first used 85% phosphoric acid to remove the enamel, this method has become the professional standard for preparing the enamel. However, the acid concentrations decreased. According to literature, acid concentrations range between 2% to 85% and the application time differs between 15 to 120 seconds [47,48] . While there is variation in reported concentrations and durations, a consensus among researchers suggests that utilizing phosphoric acid concentrations ranging from 35% to 40% and applying it for a duration of 15 to 60 seconds is advisable[30,49] . Enamel etching has the potential to trigger structural alterations, although these changes can be reversed when utilizing lower concentrations and shorter durations of etching[50].

The current state of literature asserts that etch and rinse adhesive systems possess the ability to establish a powerful bond with enamel [51,52]. In general, it has been observed that three-step etch and rinse systems tend to exhibit superior performance compared to two-step systems. Research findings have indicated that adhesive systems employing a three-step etch and rinse technique exhibit enhanced bonding capabilities to enamel, which makes themselves as widely recognized and considered as the "gold standard" [51].

Along with the advantages associated with etch and rinse adhesive systems, it is essential to recognize the presence of certain limitations. Due to having a number of application steps, the probability of facing application errors is elevated, which ends up resulting in a prolonged clinical application duration for these adhesives [53] .

2.2.2. Self - Etch Adhesive Systems

Researchers in the field of adhesive dentistry have made advancements in the development of new approaches aimed at managing the susceptibility of etch and rinse systems to moisture. These systems not only seek to simplify the clinical procedures involved but also aim to minimize the amount of time patients spend in the dental chair[54]. Phosphoric acid etching and rinsing steps are eliminated in self-etching adhesive systems. Alternatively, self-etching primers (SEPs) are available as a single substance that combines etchant and primer, eliminating the need for a separate clinical step[55].

The categorization of self-etching adhesive (SEA) systems is based on the clinical application procedures. The two-step self-etch adhesive (SEA) systems comprise of an initial stage involving the application of a hydrophilic acidic primer, followed by a subsequent stage involving the use of a hydrophobic bonding resin. The two components are supplied in distinct bottles [56]. The SEA system incorporates acid etchant, primer, and bonding resin within a single container. This system is commonly referred to as a "all-in-one" system.

The etching pattern observed in self-etch adhesive (SEA) systems differs from that of etch and rinse adhesive systems. The process of phosphoric acid etching results in the formation of a textured surface that bears resemblance to the characteristic pattern of a honeycomb structure. The application of this particular surface leads to the formation of substantial resin tags that penetrate deeply into the enamel. Nevertheless, the use of SEA leads to a reduction in the level of enamel etching aggression, thereby resulting in the formation of thinner and smaller resin tags [57] .The predominant bonding mechanism observed in the structure of self-assembled enamel (SEA) is attributed to the chemical interactions between the phosphate group and calcium ions present within the enamel.

Self-etching systems offer numerous benefits, such as expedited and simplified application procedures, decreased chair time, enhanced patient comfort, and a more conservative approach due to diminished enamel demineralization. A reduction in the number of clinical steps can also lead to a decrease in application errors, as it reduces the level of technical sensitivity required[58,59] .

Based on the current research, it has been proposed that self-etching adhesive systems exhibit reduced shear bond strengths and induce lesser demineralization in enamel when compared to etch and rinse adhesive systems[55,60]. Moreover, there have been suggestions indicating that the rates of bond failure are higher when using self-etch adhesives (SEA) compared to conventional etch and rinse adhesives[61]. Nevertheless, some scientists claim that there is a lack of substantial disparities in bonding values between conventional and self-etching systems [58,62] . Bishara et al. [63] found that self-etch adhesive (SEA) systems exhibit lower bond strengths compared to conventional etch and rinse adhesive systems. However, it should be noted that the observed outcomes appear to be clinically acceptable. According to a comparative study on the bond strength values

of various self-etching primers (SEPs), it was found that Transbond SEP exhibited the highest bonding values[64]. According to Attar et al.[65] , it was proposed that both one-step and two-step self-etching adhesives possess mechanical properties that are suitable for clinical applications. In summary, it can be concluded that self-expandable stents (SEAs) possess mechanical strength that meets clinical standards, and they are increasingly being integrated into routine clinical procedures.

2.2.3. Universal Adhesive Systems

Universal adhesive systems are a recent addition to the field of adhesive dentistry. These adhesives are commonly known as multi-model or multi-purpose adhesives due to their ability to be utilized as either etch and rinse adhesives or self-etching adhesives, depending on the clinician's preference.

The composition of universal adhesives differs from that of self-etch adhesive (SEA) systems. The universal adhesives contain monomers that have the ability to form both chemical and micromechanical bonds.[66]

Additionally, it should be noted that universal adhesives have the potential to include silane, which can effectively eliminate the need for a separate silanization procedure when bonding to ceramics or resin composite materials[39].

2.2.4. One Step Adhesive Systems

In the field of orthodontics, there has been an introduction of one-step adhesive systems in recent years. The incorporation of primer and adhesive into the paste eliminates the need for a separate primer application step in these systems. The composite paste is applied directly onto the etched enamel without any prior application of a primer or adhesive resin. Before bracket placement, it is necessary to clean the enamel surface using pumice, followed by a 30 second application of phosphoric acid for etching. Subsequently, the surface should be thoroughly rinsed and dried, following the standard protocol employed in etch and rinse adhesive systems.

2.2.5. Glass Ionomer Adhesive Systems

Glass ionomer adhesives refer to substances that possess the ability to establish a chemical bond with dental tissues in the absence of any intermediary agent. The composition of these substances comprises polyalchenoic acid polymers, glass filling particles, and water[67]. Dentin can be chemically and micromechanically bonded by them.

Resin modified glass ionomer adhesives are formulated by incorporating resin constituents into glass ionomer adhesives with the intention of enhancing their adhesive characteristics. The polymerization mechanism of resin-modified glass ionomer adhesives differs from that of conventional glass ionomer adhesives. The mechanisms they possess exhibit dual curative properties. The primary polymerization reaction is initiated by the application of a curing light, which leads to the polymerization of resin monomers. The occurrence of secondary polymerization reactions is contingent upon acid-base reactions. These systems establish a connection with dentin through a combination of chemical and micromechanical bonding mechanisms.

According to reports, resin modified glass ionomer adhesives exhibit greater shear bond strength in comparison to conventional glass ionomer adhesives[51]. The literature demonstrates that Summers et al.[68] have reported a notable disparity in bonding strength between resin modified glass ionomer adhesives and conventional etch and rinse adhesive systems when used for bracket bonding. Nevertheless, the previous research also demonstrates that the bonding values of resin modified glass ionomer adhesives are considered clinically acceptable. Additionally, when resin modified glass ionomers are employed, the process of removing adhesive remnants during debonding is facilitated.

2.3. Relaps in Orthodontics

Relaps is one of the main risks in orthodontic treatment. It is defined as; any change from the obtained final tooth position at the end of the orthodontic treatment. It could be the return of the teeth to its original position, or any other unwanted movement of the teeth.[69] Since the orthodontist aims to correct the malocclusion of the patient and to offer the patient an aesthetic and a functional occlusion, they also aim to keep it permanent.[70] Regarding the relaps which occurs, orthodontist discussed over the years

to find a solution to keep the stability. They made their researches on the aetiology of relaps, retention protocols, adhesion protocols used with retention, patients growth pattern, relaps with extraction versus non extraction treatments, relaps with expansion, the effect of incisors inclinations and much more other tooth movement which can effect the magnitude of the relaps.

2.3.1. Aetiology of Relaps

Relaps should be accepted as a part of the orthodontic treatment. While some patients won't have any relaps at all, it is found in the literature that majority of the cases show some degree of relaps.[69] Regarding this situation, the orthodontist should inform the patient in advance about the relaps which may occur according to the patients growth and the treatment protocol which will be used. They should also be aware to the need for retainers or/and any other retention procedures. Patient will be educated about the retainer failures, broken vacuum-formed retainers and also about how to maintain the hygiene around fixed and removable retainers.

It is known that the equilibrium is the main key of the orthodontics and that the stability can be accomplished only if the forces derived from the periodontal and gingival tissues, the orofacial soft tissues, the occlusion and the posttreatment facial growth and development are in balance. [71,72]

It is recommended that relaps occurs for several reasons: periodontal or gingival factors, soft tissue factors, occlusal factors, posttreatment facial growth and development, lower labial segment, arch length and arch width, effect of third molars. [73]

2.3.1.1. Relaps due to periodontal or gingival factors

For the tooth movement to occur, remodelling of the surrounding periodontium is necessary. Since the different parts of the periodontium remodel at different time scale, this time is required for the bone, periodontal and gingival fibers to remodel to the new position (Figure 2.2). [74]

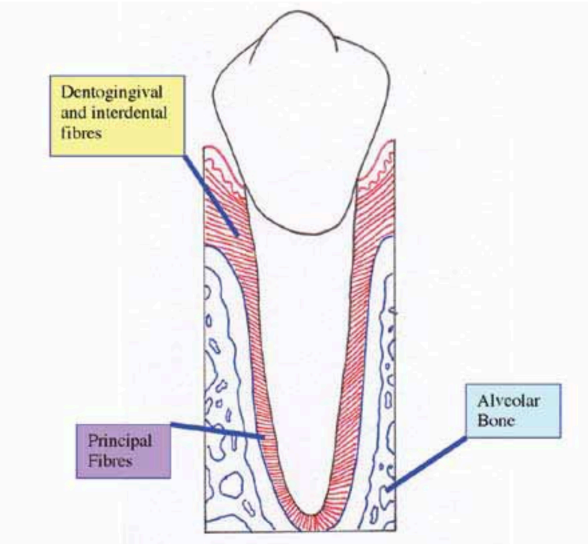

Figure 2.2 Differential remodelling of the periodontium.

After tooth movement, significant residual forces are still present in the periodontium tissues.[72,75–77] The greatest portion of the principal periodontal fibers renew in around 3 - 4 months, the surrounding alveolar bone in a month, while the elastic fibers within the interdental and dentogingival fibers might take up to eight months to remodel [74,75,78]. It's possible that certain fibers will need much more time to restructure.

The clinical importance is that the fibers will pull the teeth back towards their previous position if they are not kept in their new location for a sufficient amount of time to allow for fiber remodeling. We can see this change more obviously with the correction of rotations and space closure since lower lateral incisors, canines and second premolars are being more likely than other teeth to migrate back to their original places [78]. The extra difficulty seen with the rotations can either treated with an extended retention or by cutting the dentogingival and interdental fibres using circumferential supracrestal fiberotomy or pericision [79–81].

2.3.1.2. Relaps due to changes in soft tissues

The teeth lie in an area of balance between the lips and cheeks labially, and the tongue lingually. This theoretical area of balance is known as the neutral zone [69]. Since the aim is to keep the stability, it should be clear to proceed the treatment within the

boundaries set by the soft tissue environment [82]. To prevent the risk of relaps, at the end of the treatment, the teeth should be in this neutral zone.

Although the principle of positioning the teeth in the neutral zone is helpful, there are two significant issues for the dentist in practice. First, we are unsure of the neutral zone's precise location. Second, the neutral zone may alter as a result of changes in muscle tone with aging[69].

2.3.1.3. Relaps due to occlusal factors

Angle believed that the occlusion is really important for the posttreatment stability[83]. He thought that the facial balance and stability will occur only if all the teeth are aligned with a normal molar relationship. One of the finest example to this situation is the correction of crossbite. Once the anterior crossbite is corrected with enough overbite, no retaining appliances are required for the stability.

In 1972 Andrews[84] integrated this system with what we call "Andrews six key to normal occlusion". These six characteristics listed as; inter-arch molar, premolar and canine relationship, mesiodistal crown angulation, buccolingual crown inclination, absence of rotations, presence of defined proximal contacts and an aligned curve of spee. However, these treatment objectives, only focus on static traits without taking into account the functional aspects of the occlusion.

In 1976, Roth[85] introduced that the fundamentals of the occlusion should be followed as; canine guidance during laterotrusion, immediate anterior guidance during protrusion, maximum intercuspidation of the teeth with the jaw in centric relation, appropriate occlusal contacts of posterior and anterior teeth in centric relation and the sides equal balance.

Centric relation (CR) and maximum intercuspidation (MI) are also important in diagnosis and finishing of the cases in orthodontic treatment. The posture of the jaw when the condyles are in a stable orthopedic position is often referred to as CR[86,87]. Maximum intercuspal position refers to the mandibular posture associated with occlusion. From the diagnosis until the time of treatment completion, the orthodontist must take CR and MI positions into account. When this process is ignored, it may be possible to make a

wrong diagnosis and treatment plan which will cause either TMJ problems, headaches or a relaps in the occlusion at the end of the treatment[88].

A suitable occlusion and a correct interdigitation with a suitable molar relationship and overjet will avoid the dental migration. So the presence of all static and functional occlusion provides the way for the short and long-term effectiveness of the orthodontic treatment. Even though, it shouldn't be forgotten that this single element may not be sufficient to sustain the orthodontic movement gained, but it will strengthen stability and may reduce tooth migration[88].

2.3.1.4. Lower Labial Segment

It is mentioned that any movement of the lower labial segment which is away from the narrow zone of labiolingual balance is probably going to be unstable[89]. Still, there are some exceptional cases which may be stable. Proclination movement of the lower incisors with Class II cases when the incisors are retroclined by a bad habit like finger sucking or lower incisor stability with the mandibular surgery of the Class III cases can stay stable even though we work with the lower labial segment. It should be kept in mind that the existing lower arch form is the best template to soft tissue balance, and the treatment planning should be done by accomplishing the upper arch around the lower[73,90].

2.3.1.5. Arch Width

With any case if the arch form changes, there is a risk of relaps of the orthodontic treatment. It is seen that changes in patient's intercanine width is more unstable than the changes in the intermolar width[69]. To obtain the stability, it is proven to keep the original arch form. So it is told to stay in the lower arch forms region and to establish the upper according to the lower. Eventhough the concept about staying in the neutral zone is preferred to avoid the orthodontic relaps, there are two problems that the clinicans encounter. First is that we do not know the exact position and dimensions of neutral zone and the second is that the neutral zone changes with age.

To summarize, it is found that evet after 10 years of retention; cases with serial extraction[91], premolar extraction[92], polydiastema cases[93], decompensation of Class III

cases[94], and even with non treated normal occlusions[95], the arch width tends to reduce. So the maintenance of the original inter canine width does not guarantee stability.

2.3.1.6. Arch Length

Same with arch width, arch length also found to be decreased in both extraction[96] and non extraction[97] cases furthermore with untreated cases[95], cases with serial extraction[91], polydiastema[93] or presurgical proclination[94]. The decrease of the arch width and length found out to be continued between ages 20-30, but it seemed to cease after age 30.

Regarding these, patients must be fully aware of both our limits and their own responsibility for upholding the treated outcome. The orthodontist should be prepared for instability rather than making the assumption that stability will ensue.

2.3.1.7. Relaps due to Third Molars

It is found that there is little effect of the third molars on the crowding of the lower labial segment. Since this effect is found clinically insignificant[98], NICE[99] (National Institute for Health and Clinical Excellence) guidelines recommended that the third molars should not extract just to reduce the risk of relaps in the lower labial region.

2.3.1.8. Relaps due to Growth

For a long time it is considered that the growth is completed at the end of puberty. Despite this, now it is obvious that the facial growth continues throughout life[100]. The speed of the growth changes among every individual and it is impossible to estimate the exact time of this change since it continues throughout adult life. In addition to the relapse which will occur due to the treatment itself, there is always a relapse which may occur in the sagittal[101], vertical[102] or lateral[103] skeletal dimensions. In untreated adult individuals in their 30s and 40s, it is seen that the dental arch length is shorten, a decrease in intercanine distance and increased anterior crowding[104,105]. Also, there was found an

increase in the lower facial height which is due to skeletal changes and also to continuous tooth eruption[104].

Therefore, the total stability can not be seen neither in the craniofacial skeleton nor in the dentition[73]. When evaluating the orthodontic treatments long term results, it is impossible to distinguish if the relapse occurs because of the orthodontic movement or due to natural growth changes[106]. Along with this, Vaden et al.(1997) showed that the real relapse occurs soon after the orthodontic treatment, while the change which time is usually because of the normal aging process[107].

Regarding the patients growth pattern, it will be useful to make overcorrection to oppose the relapse which will occur. Despite all the precautions, there are not any instructions about the appropriate duration of the retention for each case. However, it is known that polidiastema cases, arch expansion and alignment in patients with cleft palate requires life time retention.

2.4. Retention

Retention should be known as the final stage of the orthodontic treatment. The patient should be informed at the beginning of the treatment about the retention and their responsibilities including how to look after the retainers. Retention aims to keep the teeth at the final correct position which is planned.

Both a retention phase and a postretention phase of therapy are present after orthodontic treatment. Retention phase compromises the time interval which includes the remodelling of the periodontium after the skeletal and dental changes occur with the orthodontic treatment[108]. It is widely agreed upon that the retention phase is finished one year after the end of treatment[73]. On the other hand, the postretention phase continues along life time. With the changes caused by the growth and the development, the balance of the soft tissues can change which will lead to an unwanted teeth movement.

Regarding the reasons mentioned within the previous titles, it is unavoidable to use an appropriate retention protocol following the removal of the active orthodontic appliance[109]. It was proven with an experimental study that if the patient doesn't use any retention appliance after an orthodontic treatment, there occurs a serious worsening in corrected tooth rotations, lower incisors alignment and overjet in only 4 weeks[110].

Littlewood et al came to the conclusion in their Cochrane systematic review that there is not enough data to support orthodontic retention approaches[111]. The majority of relapses are said to happen in the first two years after retainers are removed[112]. Eventhough there isn't any agreement about how long the retainers should be used, orthodontists agree that the patient should use retainers as long as they want to keep their alignment the way desired[113]. Regarding all this, the clinician must be in consultation with the patient to decide the most convenient retention protocol for each case[114].

2.5. Retention Appliances

Retainers are orthodontic devices which are used to prevent a relapse or return to the original malocclusion after the orthodontic treatment. The studies showed that significant amount of relapses mostly occur in the alignment of the mandibular anterior teeth. To prevent this relapse, different types of removable or fixed retainers are used for a particular duration or for a life time period. The retinaers may be roughly divided into fixed and removable categories.

2.5.1. Removable Retention Appliances

Removable retainers, as the name implies, may be taken out by patients, enabling them to thoroughly clean the area surrounding their teeth and to wear them just part-time if required. To reduce the risk of relapse, however, there are specific circumstances when retainers are necessary continuously every day, and in these cases a fixed retainer will frequently be needed[109].

In 1919, Charles Hawley[115] has designed the hawley retainer and it has been used as the most popular retention appliance for a long period (Figure 2.3). Sheridan et al.[116] presented the Essix appliance (DENTSPLY Raintree Essix Glenroe, Sarasota, FL, USA) in 1993 since it is more patient friendly, easy to use, esthetic and cheaper (Figure 2.4). Hawley retainers are acrylic, whereas Essix retainers are vacuum formed. Now a days, clinicians use both hawley and essix retention appliances in their practice. Since they are both removable, the patient compliance should be one of our main concern. The study of Kouguchi et al showed that %60 to %70 of the patients forget the need to wear the retainers after the orthodontic treatment[117].

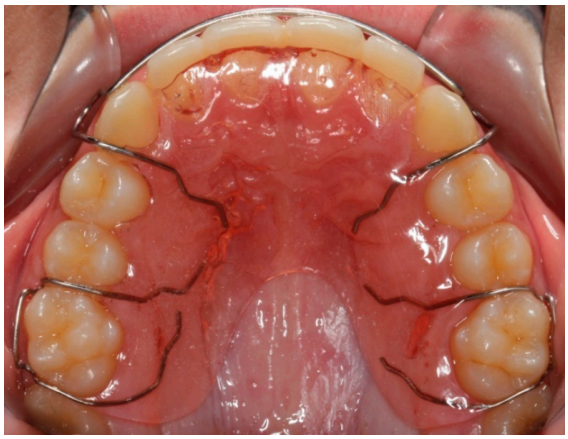

Figure 2.3 Hawley Removable Retainer Occlusal View

Figure 2.4 Vacuum Formed Retainer Occlusal View

Figure 2.5 Positioner

The recall visits of the patient after an orthodontic treatment is usually planned in 6 weeks, 3 months, 6 month and a year after debonding. This procedure goes as one year follow ups each year. Still, not all the patients obey to their recall appointments where their retainers are being controlled. So patients should be informed about the risks they will get if they don't participate to their recall appointments in advance of their orthodontic treatment if they do not ask for any relapse.

Despite all this, even though Hawley has been favored historically, nowadays, VFRs seems to gained the place since they can be made in-house[118] and since they are more economic.

Even though VFRs are more preferred by the patients conversely to hawley's, the patient compliance in overall with removable retainers are hard to accept. That's why, fixed retention should be assessed as a preferred retention method after an orthodontic treatment[108].

2.5.2. Fixed Retention Appliances

Fixed retainers are the appliances used with an acid etching method. With the invention of acid etching technique, in 1973 Kneirim introduced the use of fixed bonded retainers[119]. These retainers can be used either individually after the treatment or with the combination of vacuum formed retainers. Eventhough some clinicians use the vacuum formed retainers most frequently, it has been listed that there are some precise indications for fixed retainers. These indications are; closed midline diastema, polidiastema cases, severe rotations, significant incisor proclination, significant increase in lower intercanine width, openbite cases treated nonsurgically, teeth with no opposing tooth and teeth with the lost of periodontal support[120,121]. There are basically 2 types of fix orthodontic retainers. The first is the one which is only bonded to the canines: rigid mandibular canine to canine retainers. The second is the flexible spiral wire retainers.

2.5.2.1. Rigid Canine and Canine Retainers

The rigid retainers are only attached to the canine teeth which is useful for keeping the intercanine width. With this retainer bonding procedure, thicker 0.032 inch wires are used with commonly stainless steel wires and sometimes with also nickel-titanium wires.

The problem with rigid canine to canine retainers is that it is hard for them to maintain the incisor alignment since it is difficult to control the individual incisor movement. To prevent this problem; when only bonding to canines, an interproximal reduction is found useful to create contact surfaces instead of points to enhance the stability. Eventhough, this application only prevents minimal rotations but does not prevent bodily tooth movements[122] (Figure 2.6). It should taken in consideration that if there is a risk of relapse for each tooth separately, it is wiser to bond the retainer to each tooth.

Figure 2.6 Lower Canine and Canine Non-Flexible Cylindrical Wire

2.5.2.2. Canine to Canine Retainers

The wires used for lingual retainers are developed throughout the time and they are categorized into generations. Eventhough plain round or rectangular orthodontic wires were used at the beginning as fixed retainers[123], in 1977 Zachrisson[124] presented the advantages of multi-stranded wires. Afterwards, Zachrisson applied triple stranded wire to all anterior teeth in his studies (Figure 2.8). However, with his studies and experiences for 20 years on retainers, he reported that 0.0215 inch 5-stranded wires serve better results based on failure rates regarding the follow-ups[125].

Regarding all the bonded retainer history, we see that there are several material types taken together with a bonding adhesive system. Stainless steel wires; multistranded stainless steel (SS) appears to be the most commonly used wire type for bonded retainers

[120,125–128]. Figure 2.7 shows a range of SS wires used for bonded retainers[129]. These SS wires can be round or rectangular in cross-section and they are usually composed of 3-6 fine strands of wire either braided or arranged co-axially[125]. The wire sizes commonly changes from 0.0175'' to 0.0215''. SS wires which have greater diameter are more rigid so they have lower risk of wire fracture, but they are more prone to failure since they lack the flexibility[125].

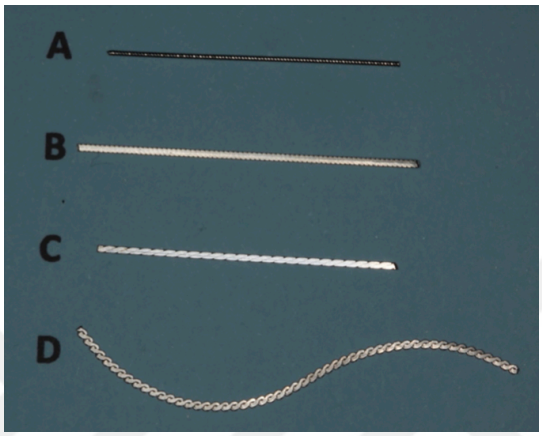

Figure 2.7 A range of ss wires used for bonded retainer fabrication. **(a)** 'Penta One Coaxial': 0.0215" (Ortho Organizers, Carlsbad, California). **(b)** 'Flattened multistrands': 0.01" * 0.03" (Sheboygan, Wisconsin). **(c)** 'Braided Retainer Wire' : 0.01" * 0.028" (Ortho Technology, Lutz, Florida). **(d)** 'Ortho-Flextech' : 0.016" * 0.038" (Reliance Orthodontic Products, Itasca, Illinois).

Figure 2.8 5 stranded SS wire retainer bonded canine to canine

Newly bonded retainers can be manufactured using CAD-CAM systems with a new technology[123] (Figure 2.9). While one of the technique is used with the bending of

the prefabricates wire by a handle of a machine, the other technique is producing the retainer by carving out of a block of wire. It was found that there were seen less plaque and gingival inflammation with CAD-CAM retainers[130].

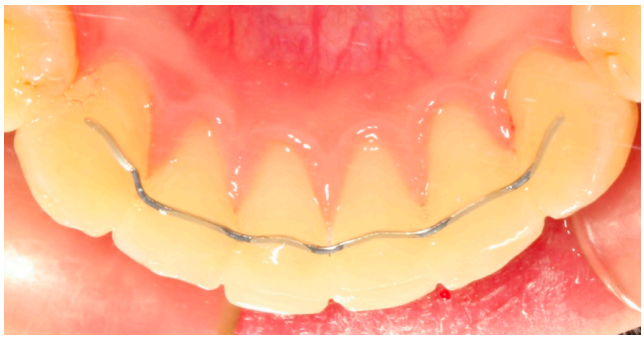

Figure 2.9 Retainer wire canine to canine manufactured using CAD-CAM system

2.6. Bonding Techniques of Fixed Retainers (Direct and Indirect Technique)

If the patient is good with his/hers oral hygiene, fixed retainers need minimum patient compliance. The disadvantages of the fixed retainers are that they need more chair time than the removable ones and they tend to break either because of the patient use or because of the missed bonding procedure[131].

There are different bonding techniques of the fixed retainers. They are known as the direct and indirect technique. The most used technique is known as the direct technique. With both techniques the enamel surface is prepared regarding the usual adhesive bonding procedures which we will list afterwards. With the direct retainer bonding technique the wire is not prebended either by the dentist or the technician. The wire is directly fixated in the mouth by several methods, mostly by dental floss, elastics, ligature wire or either with finger pressure[132]. With any of this methods this bonding procedure takes time and needs experience since it has risk of contamination from saliva and moisture, which can cause failure of the bonding[133]. To eliminate these problems the indirect technique is introduced.

The indirect technique is more comfortable for the patient with less chair time needed for the dentist. The wire is prebended by a laboratory technician or by the dentist. A silicone key is prepared on the incisors to direct the correct position of the wire during bonding. This silicone key also inhibits the etched surface from contamination. Beside these advantages, the indirect technique includes an impression before the bonding of the

retainer which involves an extra appointment and also an extra laboratory time which may cause an extra expense[132].

2.6.1. Factors which Effect the Bonding System

Regarding these techniques there are also some factors which effect the bonding.

2.6.1.1. Properties of the Enamel Surface

In order to understand the bonding systems and the adhesion, it is first essential to know the enamel structure. The enamel is consists of 95% inorganic material, 4% organic matrix and 1% water by weight. 86% inorganic material, 2% organic matrix and 12% water by volume. Enamel's chemical structure consists of highly mineralized crystalline. Regarding these properties, the enamel is more suitable for bonding of the dental adhesives[39].

2.6.1.2. Cleaning of the Enamel Surface

The use of an appropriate technique with careful cleaning of the enamel, etching and drying of the teeth is one of the most important things to inhibit the failure risk. To achieve a better adhesion, the enamel at the beginning should not contain any dental plaque. The teeth should be polished with a non-fluoride oil-free pumice in advance[134].

2.6.1.3. Etching of the Enamel Surface

After the enamel surface is cleaned totally, the etching of the enamel is the next step for a propriate bonding. It was analyzed that after the acid etching technique, 10 μm of the enamel surface is resorbed and that 5-50 μm is detected. With this application the enamels surface energy and adhesion to the enamel increases and as an advantage of this rough enamel structure, resin based materials can penetrate deeper and create a strong connection[135].

2.6.1.3.A. Acid Etching Technique

Etching process aims to increase the surface area and to obtain a high energy hydrophilic surface area rather than a low energy hydrophobic surface area. In 1955, Buonocore developed the etching technique with phosphoric acid to increase the bonding values of unfilled methylmethacrylate resin to the enamel surface. Later, various acids such as phosphoric, citric, hydrochloric, maleic and pyruvic acids were tested under laboratory conditions and as a result, phosphoric acid was the preferred etching agent[136].

With the phosphoric acid etching technique, the enamel becomes a deep and uniform demineralization area. By etching, different chemical changes in organic matrix and decalcification of the inorganic substance is gained. As a result, enamel surface becomes more suitable for adhesive attachment[44,46,137,138]. The success of the etching process depends on the isolation of the teeth and the prevention of contamination of the roughened enamel surface with saliva or water. Contamination with organic fluids during or after etching causes glycoproteins to precipitate on the enamel surface, greatly reducing the bond strength of restorative materials. In such a situation, it is recommended that the etching should be done again[139].

2.6.1.3.B. Air Abrasion Technique

Apart from different adhesive systems with different clinical applications, there are also other enamel preparation methods like air abrasion. Air abrasion consists from aluminum oxide particles with high speed which are delivered by air pressure. Accelerating particles hit the tooth surface, causing rapid removal of the tooth substance. Many factors such as air pressure, particle size, working time and microstructure of the surface to be applied must be taken into account in order to ensure a proper bonding with air-abrasion[140].

It was shown in some in vitro studies that even without an additional acid etching method, the air abrasion creates similar bonding surfaces to phosphoric acid etching[141,142]. Chan et al. and Moritz et al. reported that the best grip strength and microleakage values were obtained by using the air-etching method with acid[142,143]. Before bonding any orthodontic attachment or retainers, intraoral enamel air abrasion method is used by orthodontist to clean and also to prepare the enamel surface[6].

2.6.1.3.C. Laser Etching Technique

The word “Laser” comes from the first letters of Light Amplification by Stimulated Emission of Radiation. The laser device was first invented by Theodor H. Maimann in 1960 using a ruby crystallin. Afterwards, different wave lengths of laser were presented. Laser application causes thermal effects on the enamel surface. According to the laser type which is used and to the amount of the energy, there occurs an irregularity and roughening of 10-20 μm in depth just like with the acid etching method[144–146]. We use the laser for the abrasion of enamel, root canal preparation, removal of the caries or fort he cavity preparation.

2.6.1.4. Adhesives Used for Fixed Retainer Bonding

To achieve a better stability without an active patient cooperation, fixed Retainers are obligatory. The main risk of the fixed retainers is the risk of detachement. Main reasons for an unexpected breakages are listed as insufficient adhesive usage or distortions during fitting, unwanted trauma to the retainer, metal fatigue of the retainer or unwanted occlusal contacts of the composite with the adjacent jaw, insufficient shear bond strength[147] and wire pull out resistance[148]. Moreover, since the composite resin is exposed to the oral cavity, the material hardness, wear resistance and water absorption[149] are also important mechanical characteristics fort he stability of the retainers.

Different types of resin composites can be chosen to attache the wire to the enamel. Knowing the invitro studies about the bonding strength, it was seen that the detachment type is usually cohesive which takes place between wire and the composite[150,151]. In order to achieve a long lasting retention, the adequate characteristics of the adhesive is needed.

Fixed orthodontic retainers can be attached to the teeth with different kinds of composites. Through history different kinds of orthodontic and restorative adhesives have been used to be analyzed for the bonding of fixed retainers. It was found that thinning of the composite showed the best handling characteristics[152]. Some companies have introduced adhesives which are made just for bonding the lingual retainer and they announced that these adhesives are easy to use and that they have the proper viscosity to offer the orthodontist a better shape and finish. Flowable resin composites have also been

developped with different variety of formulas and viscosities. Recently the use of flowable composites with increased resin contenent of traditional microfilled composites have been recommended for bonding lingual retainers[152].

2.7. Gastroesophageal Reflux Disease (GERD)

2.7.1. Definition of GERD

Frequent occurrences of gastroesophageal reflux (GER) throughout the day are, in fact, considered a normal physiological phenomenon. Gastroesophageal reflux disease (GERD) is the term used to describe the pathological condition that arises when gastroesophageal reflux (GER) leads to unpleasant symptoms and associated complications[153]. Gastroesophageal reflux disease (GERD) is a disorder of the gastrointestinal system characterized by the atypical backflow of gastric substances into the esophagus and occasionally extending to the oral cavity, resulting in various symptoms and potential complications[2]. Gastroesophageal reflux disease (GERD) is associated with both typical symptoms, such as heartburn, regurgitation, and chest pain, as well as extraesophageal symptoms, including chronic cough, laryngitis, asthma, and dental erosions[154].

Historically, gastroesophageal reflux disease (GERD) was characterized as erosive esophagitis and regarded as an acute disorder that necessitated short-term treatment. Currently, there is a consensus among experts that there exist clinical observations that necessitate the implementation of long-term therapeutic approaches[2]. Given the persistent nature of gastroesophageal reflux disease (GERD), its effective management necessitates ongoing utilization of pharmaceutical interventions and adjustments to one's lifestyle. Hence, the presence of numerous drawbacks, such as the imposition of financial stress and a decrease of patients' quality of life, has been observed[154].

2.7.2. Epidemiology of GERD

Recent studies have revealed that the prevalence of gastroesophageal reflux disease (GERD) exhibits regional variations across the globe. In North America, the

prevalence ranges from 18.1% to 27.8%. In Europe, it ranges from 8.8% to 25.9%. East Asia shows a prevalence range of 2.5% to 7.8%. The Middle East exhibits a prevalence range of 8.7% to 33.1%. Australia reports a prevalence of 11.6%, while South America reports a prevalence of 23.0%.

There was a modest yet significant association observed between the presence of gastroesophageal reflux (GER) symptoms and several factors, including age of 50 years or older, smoking, use of nonsteroidal anti-inflammatory drugs (NSAIDs) and/or aspirin, obesity, and low socio-economic status. The prevalence of GER symptoms was found to be higher among individuals exhibiting these characteristics[154].

Turkey is geographically positioned between the Eastern and Western countries. Epidemiological studies conducted in Turkey have indicated that the epidemiology of gastroesophageal reflux disease (GERD) in our country, as well as its associated complications, exhibit similarities with both of these groups due to Turkey's geographical location. The prevalence of gastroesophageal reflux disease (GERD) is comparatively lower in Eastern countries, while it is higher in Western countries. Furthermore, it is worth noting that regurgitation is predominantly observed in Eastern countries, while heartburn is primarily prevalent in Western countries.

The prevalence of gastroesophageal reflux disease (GERD) in Turkey exhibits similarities to that observed in Western countries[155,156], while displaying a higher prevalence compared to Eastern countries[157]. In Turkey, the prevalence of regurgitation is higher compared to heartburn, similar to other Eastern countries. The study revealed that the incidence of reflux in the regions of East Anatolia, Central Anatolia, Mediterranean, and Black Sea was comparatively higher than in other regions of Turkey. Furthermore, it was observed that the prevalence of reflux was higher among females than males[158].

2.7.3. Risk Factors of GERD

There is evidence to suggest that certain factors, namely body mass index, family history of gastroesophageal reflux disease (GERD), and alcohol use, may contribute to an increased risk of developing GERD [159]. According to existing literature, certain

medications and dietary choices have been implicated in potentially augmenting the risk of developing gastroesophageal reflux disease (GERD) and may play a role in the underlying pathophysiological mechanisms of acid reflux. Various drugs have been identified as potential triggers for symptoms of gastroesophageal reflux disease (GERD). These include aspirin and other nonsteroidal anti-inflammatory drugs (NSAIDs), nitroglycerin, calcium channel blockers, anticholinergics, antidepressants, sildenafil, albuterol, and glucagon. Coffee, chocolate, and high-fat meals are recognized as dietary factors that have the potential to induce symptoms of gastroesophageal reflux disease (GERD). Nevertheless, the existing body of research presents inconsistent findings concerning the potential impact of carbonated beverages on gastroesophageal reflux disease (GERD), as well as the role of tobacco smoking in this regard. The study conducted by Kahrilas[160] reveals an insufficient correlation between the consumption of carbonated soft drinks, excessive food intake, and rapid eating habits with gastroesophageal reflux disease (GERD).

2.7.4. Pathogenesis of GERD

Numerous mechanisms have been found to be efficacious in the pathophysiology of gastroesophageal reflux disease (GERD). The columnar mucosa of the stomach possesses characteristics that enable it to tolerate low pH levels, whereas the stratified squamous mucosa of the esophagus is open to damage caused by such low pH levels[161]. Typically, the anatomical and physiological mechanisms present in the gastroesophageal junction exert efforts to inhibit reflux[161]. The esophageal protective defense comprises antireflux mechanisms, luminal clearance mechanisms, and tissue resistance[162]. Pathological reflux is characterized by the disruption of the equilibrium between the mechanisms that protect against reflux and those that facilitate its occurrence[161]. Over time, the regurgitation of acid, bile, pepsin, and pancreatic enzymes leads to the development of esophageal mucosal damage[163]. Among these substances, gastric acid is considered the most deleterious. The coexistence of bile and pancreatic enzymes alongside acid constitutes contributing factors that augment the magnitude of the inflicted harm. In contrast, the presence of bicarbonate and growth factors within saliva serves a protective function in mitigating the detrimental consequences of reflux. The variability in the extent of esophageal damage and the severity of symptoms among individuals following exposure to acid of the same intensity can be attributed to variations in mucosal

sensitivity to acid[164]. The mucosal defensive factors play a crucial role in the prevention of gastroesophageal reflux disease (GERD) by counteracting the retrograde diffusion of hydrogen ions into the tissue of the esophagus[163].

Research has demonstrated that following meals, the gastric environment frequently exhibits lower acidity levels compared to the refluxate present in the esophagus. During periods of fasting, the pH of gastric juice in the stomach is approximately 1. However, after a meal, the presence of food buffers the acidity, resulting in a decrease in acidity levels. Consequently, the pH of gastric juice during the postprandial period ranges between 3 and 5.

It has been observed that certain substances and medications, such as cigarettes, alcohol, hot beverages, salty and spicy foods, tetracycline, doxycycline, vitamin C, bisphosphonates, and potassium chloride (KCl), may have the potential to diminish the esophageal mucosa's ability to withstand acid[164–166].

The pathophysiology of mild reflux disease involves the occurrence of acid reflux into the esophagus, resulting in an esophageal pH below 4 for approximately 4 to 15 percent of the time. This reflux primarily takes place during transient lower esophageal sphincter relaxations (TLESRs). This particular form of reflux is the most commonly occurring. Mild reflux typically manifests after meals throughout the day, while nocturnal reflux is minimal or absent[161].

The pathophysiology underlying severe reflux disease involves an increased presence of esophageal acid exposure. Severe gastroesophageal reflux disease (GERD) has the potential to give rise to more serious complications, including Barrett's esophagus or severe erosive esophagitis. Episodes of severe reflux may occur when there is a prolonged decrease in lower esophageal sphincter (LES) pressure, particularly during swallowing, and may also be associated with nocturnal reflux[161].

2.7.5. Classification of GERD

The clinical presentation of gastroesophageal reflux disease (GERD) has been categorized into two subgroups, namely esophageal and extraesophageal syndromes, by

the Montreal Consensus Group. Additionally, the extraesophageal symptoms have been further classified into established and proposed associations. There are two subgroups of esophageal syndromes, namely esophageal symptomatic syndromes and esophageal syndromes with esophageal injury.

Extraesophageal syndromes encompass a range of expressions including dental erosions, laryngitis, cough, asthma, pharyngitis, sinusitis, idiopathic pulmonary fibrosis, and recurrent otitis media[165].

The task of classifying this disease has proven challenging due to the wide range of clinical manifestations, variations in disease severity, and variations in diagnostic approaches across different individuals. The process of classification should be conducted based on the observations made during the initial examination. Akyüz and Mutluay[167] have proposed a symptomatic classification as well as an endoscopic classification.

Symptomatic Classification: The researchers have assessed the severity, frequency, intensity, and duration of symptoms to determine the categorization of GERD as either mild or moderate, based on its impact on daily activities. The condition can be classified as a mild disease when it exhibits the following characteristics: occurring less than three times within a week, having minimal impact on daily activities, and being of short duration. A condition can be classified as a moderate disease when it exhibits characteristics such as the presence of more than three features within a week, a significant impact on daily activities, and a prolonged duration[167].

The endoscopic classification of gastroesophageal reflux disease (GERD) involves categorizing the condition into three distinct groups based on the presence of reflux symptoms and corresponding endoscopic evidence. These categories include erosive reflux disease, non-erosive reflux disease (NERD), and complications. Complications of gastroesophageal reflux disease (GERD) include Barrett's esophagus, esophageal stricture, hemorrhage, and adenocarcinoma[167].

2.8. Microleakage in Orthodontics

Over the course of time, the field of orthodontics has witnessed significant transformations in its daily clinical practices, primarily due to advancements in dental

restorative adhesive systems and light curing units. A major disadvantage associated with the utilization of innovative light-cured adhesives and fast-curing units is the tendency of adhesive contraction during the polymerization process, leading to the formation of micro gaps which causes microleakage.[7] The extent of polymerization shrinkage is influenced by various factors, including the type of composite material, the percentage of filler, the presence of a diluent, the degree of monomer conversion, and the type of curing process. In the field of dentistry, the process of polymerization shrinkage induces mechanical stress within the composite material. When this stress surpasses the adhesive bond strength to enamel, it leads to the damage of the marginal seal and the formation of minor gaps between the tooth surface and the adhesive material.[168] In the field of restorative dentistry, it has been observed that excessive bond strength can lead to the occurrence of tooth or composite fractures due to the stress induced by shrinkage.

The occurrence of gaps between the adhesive material and the enamel surface may be connected to the polymerization shrinkage of the adhesive material[169]. The occurrence of gaps in dental restorations is a contributing factor to the phenomenon of microleakage, which allows for the infiltration of bacteria and oral fluids into the oral cavity[170]. The problem with this situation is that we can not detect it clinically. The issue of microleakage beneath composite materials holds significant relevance in the field of orthodontics, particularly in relation to lingual retainer adhesives. These adhesives are exposed to the oral cavity and are designed to remain in the mouth for an extended duration.

Microleakage occurring beneath orthodontic brackets has the potential to initiate various complications, including enamel discoloration, decalcification, corrosion, and diminished bond strength[171]. The adhesion between the teeth and bracket comprises two distinct interfaces: one between the composite and the bracket, and another connecting the composite to the enamel surface. The potential for microleakage occurring at the interface between the adhesive and bracket can have an impact on the failure of the bracket due to the deterioration of the bond. Conversely, the significance of microleakage which occurs at the interface between enamel and adhesive becomes more critical as it has the potential to induce enamel decalcification and initiate the formation of white spot lesions (WSL)[172]. The formation of WSL has posed a substantial clinical challenge ever since the arrival of direct orthodontic bracket bonding. The presence of WSL is observed

to be significantly higher in patients undergoing orthodontic treatment compared to those who have not received any orthodontic intervention. Orthodontic appliances facilitate the accumulation of dental plaque, leading to an increase in organic acids within the oral cavity and subsequent demineralization of enamel[173]. According to existing literature, it has been observed that a minimum of one WSL can be found in approximately 23.4% of patients who are undergoing orthodontic treatment[174]. Measurable demineralization is observed in surrounding areas of fixed orthodontic appliances within a month of their placement[173]. Furthermore, WSL can lead to aesthetic concerns persisting for over five years following orthodontic treatment[175]. Hence, the advancement of WSL poses a significant challenge in the context of fixed orthodontic interventions.

2.8.1. Microleakage Evaluation Methods

Numerous attempts have been undertaken since the beginning of early experiments to identify microleakage through the utilization of various evaluation techniques. These methods encompass the air pressure method, bacterial method, radioisotope method, neutron activation analysis, chemical tracers, electrochemical method, scanning electron microscopy, micro-CT, and dye penetration method[176].

2.8.1.1. Air Pressure Method

The air pressure method refers to the passage of compressed air through the root canal and pulp chamber of the tooth, followed by the assessment of pressure reduction within a fixed system. One of the benefits of this method is that it does not result in a loss of tooth tissues. Nevertheless, the provided information lacks specificity regarding the actual pattern of leakage, apart from just showing the smallest pathway of leakage. The air pressure method assesses microleakage by assuming that leakage is uniformly distributed along the entire margin, a scenario that is improbable and does not accurately reflect what happens in the clinic[176].

2.8.1.2. Bacterial Method

In the field of bacterial research, teeth that have been restored undergo immersion in cultured broths, followed by subsequent investigation of the underlying dentine. The

dimensions of marginal gaps that permit bacterial passage typically range from 0.51.0 μm or greater. Hence, employing this approach restricts the examination of narrower spaces that impede bacterial infiltration but permit the transit of toxins and other harmful bacterial residues[176].

2.8.1.3. Radioisotope Method

The utilization of radioactive isotopes in the medical field has significantly expanded their field of application in dental research. It has been suggested that the utilization of radioisotopes in microleakage studies yields more precise outcomes due to the smaller size of isotope molecules compared to dye particles[177]. Additionally, certain isotopes may exhibit an affinity for dental tissues or restorative materials, which can result in a potentially misleading distribution pattern on the radiograph. The radioisotope method is a qualitative approach that is highly sensitive and technique-dependent when used to determine microleakage[176].

2.8.1.4. Electrochemical Method

The application of electrochemistry in the assessment of marginal microleakage is derived from corresponding methodologies employed in the field of endodontics[178]. This technique involves the insertion of an electrode into the root of an extracted tooth, establishing contact with the base of the restorative material. Subsequently, the tooth is effectively sealed in order to mitigate the occurrence of electrical leakage, and subsequently immersed in an electrolyte bath. The potential difference is determined between the tooth and bath, and the extent of microleakage is assessed by measuring the flowing current. The utilization of this particular method is not applicable in studies conducted in living organisms, and it is not recommended to apply when used with metallic restorations[176].

2.8.1.5. Scanning Electro Microscopy

The utilization of scanning electron microscopy (SEM) is employed in the examination of the marginal adaptation of adhesive resin materials. This technique allows

for the correlation of findings obtained from alternative methods used to evaluate microleakage, thereby providing a comprehensive assessment of the behavior of resin materials. A possible limitation of using this particular method is the possibility of dealing with gaps during the process of sectioning the samples, which can subsequently lead to measurement errors[176].

2.8.1.6. Micro Computed Tomography (Micro-CT)

Micro-CT is an imaging technique that allows for the creation of high-resolution three-dimensional images by capturing two-dimensional trans-axial projections, commonly referred as "slices," of a specific sample. This method is non-destructive in nature[179]. In the field of dentistry, micro-CT helps the three-dimensional assessment of various components. These include the evaluation of the microleakage area and volume[180,181], the examination of mineral characteristics involving enamel and dentine, the analysis of structural features and alterations at the composite interfaces[182], as well as the three-dimensional evaluation of marginal adaptation[183]. Nevertheless, the higher cost of micro-CT poses a limitation to its frequent utilization.

2.8.1.7. Dye Penetration Method

The utilization of dying agents for the purpose of determining microleakage is a longstanding and widely favored technique that is presently accessible[184]. This technique enables the visualization of microleakage by utilizing contrasting colors to distinguish dental tissues and adhesive resin. The methodology involves immersing an extracted and cleaned tooth in a solution for a previously determined duration. Subsequently, the tooth is subjected to a thorough cleansing process, followed by division into sections for the purpose of evaluation, typically using magnification techniques. This evaluation aims to assess the extent of microleakage occurring at the interfaces of the bonding[176].

Dye penetration methods offer several advantages in dental applications. Firstly, water can be utilized as a solvent, providing a safe and easily accessible option. Additionally, these methods allow for the simple identification of microleakage areas through visible light, facilitating efficient detection. Moreover, the measurements

obtained using dye penetration methods are rapid and convenient. Furthermore, the cost associated with these techniques is relatively low, making them affordable. Importantly, these methods do not pose any toxicity risks and do not undergo chemical reactions with dental tissues[185]. The dye penetration technique is widely employed by researchers in in-vitro microleakage evaluation studies due to its ease of implementation and ability to facilitate rapid and precise measurements.

3. MATERIALS and METHODS

3.1. Identification of Groups

In order to examine the microleakage on different orthodontic retainers under simulated gastroesophageal reflux disease (GERD), firstly 2 main groups were created according to the PH value. Then each group was divided into 2 groups according to the surface preparation as with or without air abrasion. Then, those 4 groups were divided into 2 groups with different retainer types that will be used. Afterwards, the last 8 groups were assigned into 2 subgroups regarding the adhesive system, and a total of 16 groups were determined (Figure 3.1).

16 groups of this study are:

Group 1: pH 1.5 + without air abrasion + transbond LR + retainer type 1

Group 2: pH 1.5 + without air abrasion + flowable composite + retainer type 1

Group 3: pH 1.5 + without air abrasion + flowable composite + retainer type 2

Group 4: pH 1.5 + without air abrasion + transbond LR + retainer type 2

Group 5: pH 1.5 + with air abrasion + transbond LR + retainer type 2

Group 6: pH 1.5 + with air abrasion + transbond LR + retainer type 1

Group 7: pH 1.5 + with air abrasion + flowable composite + retainer type 2

Group 8: pH 1.5 + with air abrasion + flowable composite + retainer type 1

Group 9: pH 7 + without air abrasion + flowable composite + retainer type 1

Group 10: pH 7 + without air abrasion + transbond LR + retainer type 1

Group 11: pH 7 + with air abrasion + transbond LR + retainer type 2

Group 12: pH 7 + without air abrasion + transbond LR + retainer type 2

Group 13: pH 7 + with air abrasion + transbond LR + retainer type 1

Group 14: pH 7 + with air abrasion + flowable composite + retainer type 1

Group 15: pH 7 + with air abrasion + flowable composite + retainer type 2

Group 16: pH 7 + without air abrasion + flowable composite + retainer type 2

3.2. Calculation of Sample Size

The sample size for our study was determined using a statistical power analysis (G*Power version 3.1). With an alpha error probability of 0.05, the effect size of the groups' microleakage scores after an erosion by acidic solution was set at 1.06. Based on the analysis, a power value of 0.80 was selected, resulting in a sample size of 9 for each group. The study's overall sample size comprises 144 participants.

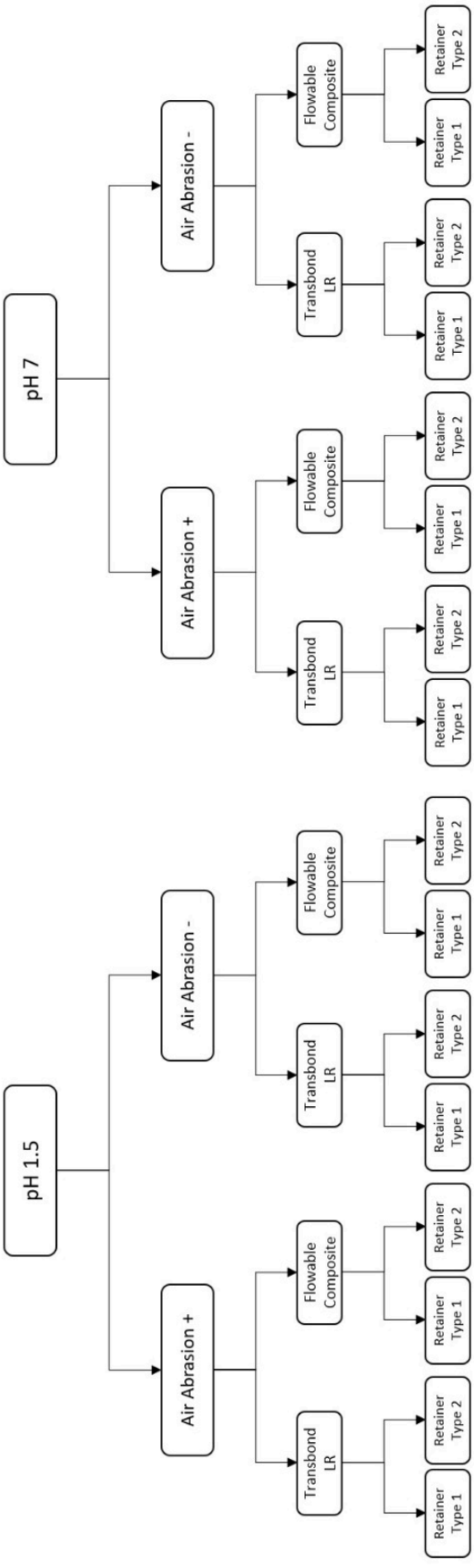

Table 3.1 Group distribution of the study

3.3. Sample Preparation

144 freshly extracted bovine incisors were collected for the study (Figure 3.1 – 3.2). Teeth which has cracks, attritions, abrasions or irregularities were excluded from the study. All the residual soft tissue and debris was removed with a scaler (Figure 3.3); and afterwards pumice paste was used to polish the specimens for 10 seconds (Figure 3.4). Subsequently, the bovine teeth were immersed in distilled water and kept at room temperature for a duration not exceeding two weeks. To prevent bacterial proliferation, the distilled water was changed on a daily basis (Figure 3.5).

Figure 3.1 Bovine mandible

Figure 3.2 Section of bovine mandible

Figure 3.3 Scale used for debris removal

Figure 3.4 Polishing brush used

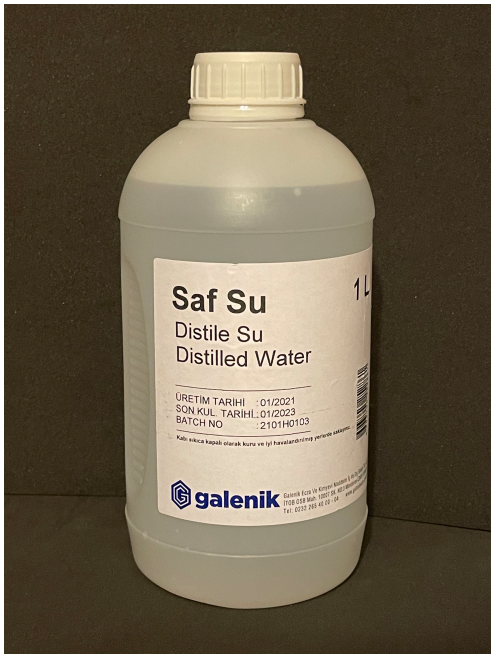

Figure 3.5 Distilled water

The bovine incisors were randomly divided into 16 groups before the experiment. Each group was consisted of 9 teeth. The teeth were dried with moisture free compressed air. All teeth apices were sealed with sticky wax (Figure 3.6 – Figure 3.7).

Figure 3.6 Sticky wax

Figure 3.7 Sticky wax used sealing the teeth apice

3.4. Surface Preparation with Air Abrasion

In order to prepare the surfaces of 8 groups, comprising a total of 72 teeth, the enamel surfaces were subjected to air abrasion using a hand piece from an intraoral air abrasion system (Hager & Werken Airsonic Mini Sandblaster, Duisburg, Germany) (Figure 3.8). Aluminum oxide particles measuring 50 µm in diameter were used together with dry compressed air at a pressure of 6 bar for a duration of 5 seconds. The handpiece was held at a distance of approximately 3 mm from the enamel surface, maintaining a 90º angle. After the air abrasion procedure, the teeth were subjected to a water stream for rinsing purposes and subsequently immersed in distilled water until the following stage of the

experiment was carried out.

Figure 3.8 Airsonic Mini Sandblaster

3.5. Fixed Lingual Retainers Used in This Study

2 different retainer wires were used in the study. The first wire is the wire which we use in the clinic straight after the treatment is done with the phase of debonding. It is a braided retainer wire of .10×.028-inch 6” length (Ortho Technology, 4614 Pet Lane Suite D-101 Lutz, FL 33559 USA) (Figure 3.9 – 3.10). It is a thin, rectangular, three strand, stainless steel, “dead soft” wire. The second wire is the wire which we use usually after taking an impression to bend the wire indirectly. It is stainless steel multi-strand wire with co-ax straight length 0215 14” (American Orthodontics, 3524 Washington Ave, Sheboygan, WI 53081 USA) (Figure 3.11). It is formed from the strands of 5 wires of equal size which are twisted around a single wire, so it is a multistrand round wire arranged coaxially (Figure 3.12).

The terms “indirect” and “direct” used in this article refer to the the chairside vs laboratory fabrications of the wires and not to bonding techniques.

Figure 3.9 Braided retainer

Figure 3.10 Section of braided retainer wire

Figure 3.11 Stainless steel multi-strand Co-Ax wire.

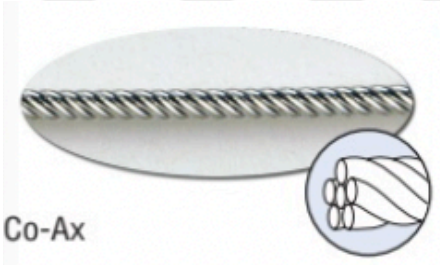

Figure 3.12 Section of six stranded coaxial round wire

3.6. Adhesive Systems Used in This Study

Initially, the teeth underwent to a complete rinse with water, followed by a process of air drying using compressed air that was both oil-free and moisture free. The buccal surfaces of the teeth underwent etching using a 37% phosphoric acid gel (Pulpdent, Watertown, MA, USA) (Figure 3.13) for a duration of 15 seconds. Subsequently, the teeth underwent a 30-second rinsing procedure with water, followed by a 10-second drying process using compressed air. The enamel that was etched exhibited a consistent and homogeneous frosted appearance. The application of Transbond XT light cure adhesive primer (3M Unitek, Monrovia, CA, USA) (Figure 3.14) was performed on the etched enamel surfaces using a micro-brush. Subsequently, the primer was subjected to light

curing using Elipar S10 LED (3M Espe, St. Paul, MN, USA) (Figure 3.15).

Figure 3.13 %37 phosphoric acid gel

Figure 3.14 Adhesive primer

Figure 3.15 Elipar S10 curing unit

Previously mentioned 2 different retainers were placed on the prepared tooth surfaces and afterwards bonded with 2 different adhesive pastes. These 2 different adhesive pastes are the ones we mostly use in the clinic. Transbond LR (3M Unitek, Monrovia, CA, USA)

(Figure 3.16) is used for the 72 bovine teeth regarding the instructions and precautions mentioned on the Transbond LR Kit box for the bonding procedure (Figure 3.17).

Figure 3.16 Transbond LR (3M Unitek, Monrovia, CA, USA)

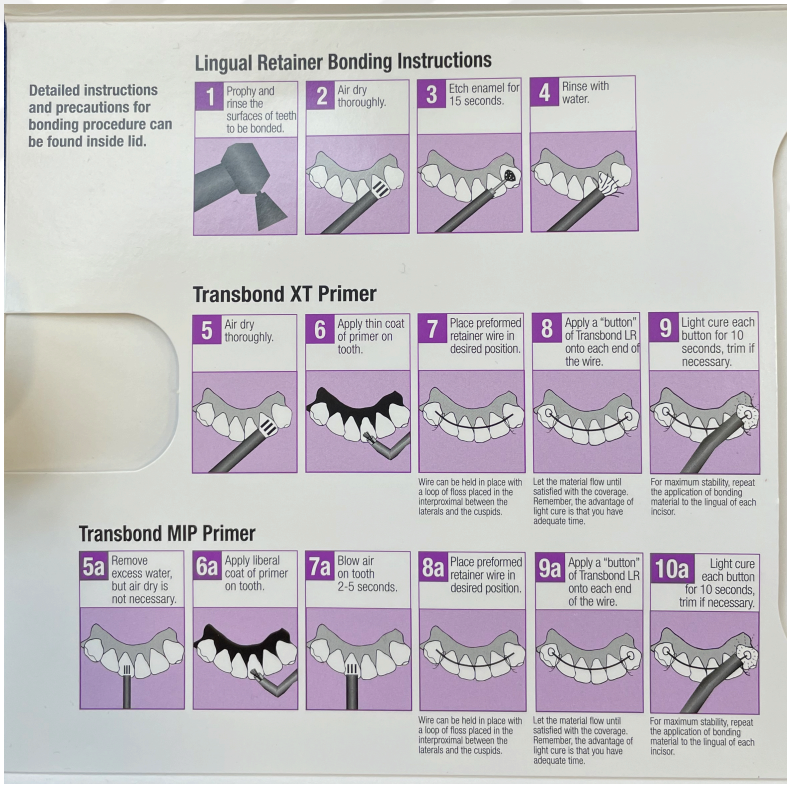

Figure 3.17 Instructions and precautions metioned on the Transbond LR capsule kit.

The other half of the samples were bonded using the other adhesive paste which is 3M Filtek Ultimate Flowable (3M ESPE, St. Paul, MN, USA) (Figure 3.18). Both of

the adhesive pastes were light cured with Elipar S10 for 10 seconds. Samples were polymerized with the 10 mm tip of the curing unit from the mesial and distal sides, positioned as close to the retainer as possible, for 10 seconds as instructed by the manufacturer.

Figure 3.18 3M Filtek Ultimate Flowable

3.7. Simulated Gastric Solution

After the retainer bonding process is done (Figure 3.19), the samples were subjected to 2 different immersion regimens.

Figure 3.19 Lingual retainer bonding process

The simulated gastric solution for the first group (Figure 3.20) was formulated at Yeditepe University Faculty of Pharmacy. This was achieved by dissolving 2.0 g of sodium chloride (NaCl) and 3.2 g of pepsin (Pepsin from gastric mucosa, P6887, Sigma, Steinheim, Germany) (Figure 3.21) in a mixture of 7.0 mL of hydrochloric acid (HCl)

with a density of 1.15 37% and water, resulting in a total volume of 1.000 mL[186,187]. The pH of the solution was determined and subsequently adjusted to a pH value of 1.5, which is indicative of a severe form of gastric regurgitation. This was accomplished with the help of a pH meter (Mettler Toledo MP220, Switzerland)[188].

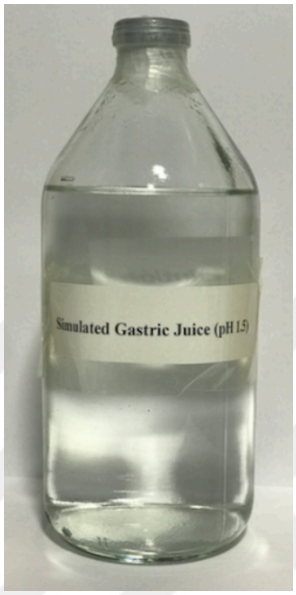

Figure 3.20 Simulated gastric solution pH 1.5

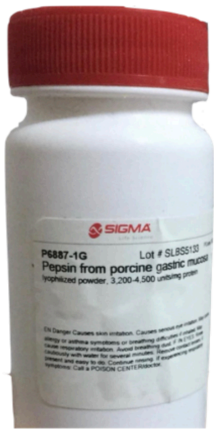

Figure 3.21 Pepsin from gastric mucosa

3.8. Artificial Saliva

The second group, consisting of artificial saliva, was prepared at Yeditepe University Faculty of Pharmacy (Figure 3.22). The composition of the saliva-substitute solution utilized in the study was adjusted based on a relevant manuscript. The modified solution consisted of 0.65 g/L potassium chloride, 0.058 g/L magnesium chloride, 0.165 g/L calcium chloride, 0.804 g/L dipotassium hydrogen phosphate, 0.365 g/L potassium dihydrogen phosphate, 2 g/L sodium benzoate, 1 g/L hydroxypropyl cellulose, 0.0003 g/L sodium fluoride, and deionized water to achieve a total volume of 1L. Additionally, 1% methyl cellulose was included to achieve an equivalent viscosity[189]. The pH of the synthetic saliva was measured and subsequently altered to a pH 7.0 using a pH meter (Mettler Toledo MP220, Switzerland).

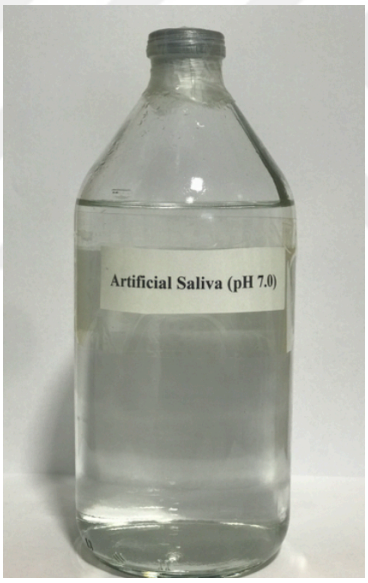

Figure 3.22 Artificial saliva pH 7.0

Immersion regimes were carefully carried out for 8 days; each immersion lasting for five minutes. The regime was distributed over a 12-hour period. Before and after each immersion, the restorations were copiously rinsed in 0.1 M phosphate buffered saline (PBS pH 7.2). When not exposed to the immersion regime, they were stored in deionized water at room temperature.

3.9. Evaluation of Microleakage

At the end of immersion period, all the tooth surfaces except 1 mm wide zone around the margins of the bonded retainer were painted with nail varnish (Figure 3.23). To minimize dehydration of the restorations, the teeth were replaced in deionized water as soon as the nail varnish dried.

Figure 3.23 After the nail varnish process

After the nail varnishing process is done to the all samples, they were immersed in 0.5% basic fuchsine solution (Figure 3.24 – Figure 3.25) for 24 hours at room temperature.

Figure 3.24 Basic fuchsine solution.

Figure 3.25 Samples immersed in basic fuchsine

Following their removal from the basic fuchsine solution, the samples underwent a rinsing process using water and the samples were left to dry. Afterwards the specimens were sectioned parallel to the lingual retainer wire with a dental diamond saw (Meisinger, Neuss, Germany) (Figure 3.26). The specimens were evaluated with OPMI Pico Zeiss surgical microscope (ZEISS, Oberkochen, Germany) (Figure 3.27) for dye penetration. A ruler was placed with the samples to set a reference for measurements. The images of

the samples were taken with a Canon EOS 700D camera (Tokyo, Japan) connected to the microscope.

The obtained sample images were subjected to analysis using ImageJ 1.46r software, which facilitated measurements through various tools (Figure 3.28). The dye penetration measurements of each specimen were recorded in millimeters, both from the mesial and distal margins of the retainers, at the interface between the enamel and adhesive.

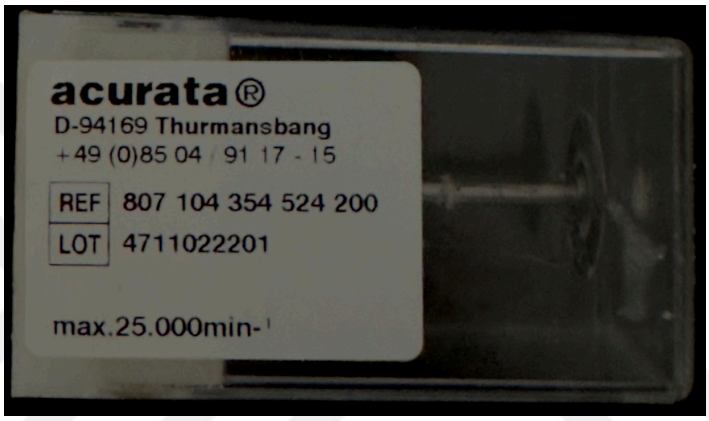

Figure 3.26 Diamond disc

Figure 3.27 Zeiss surgical microscope

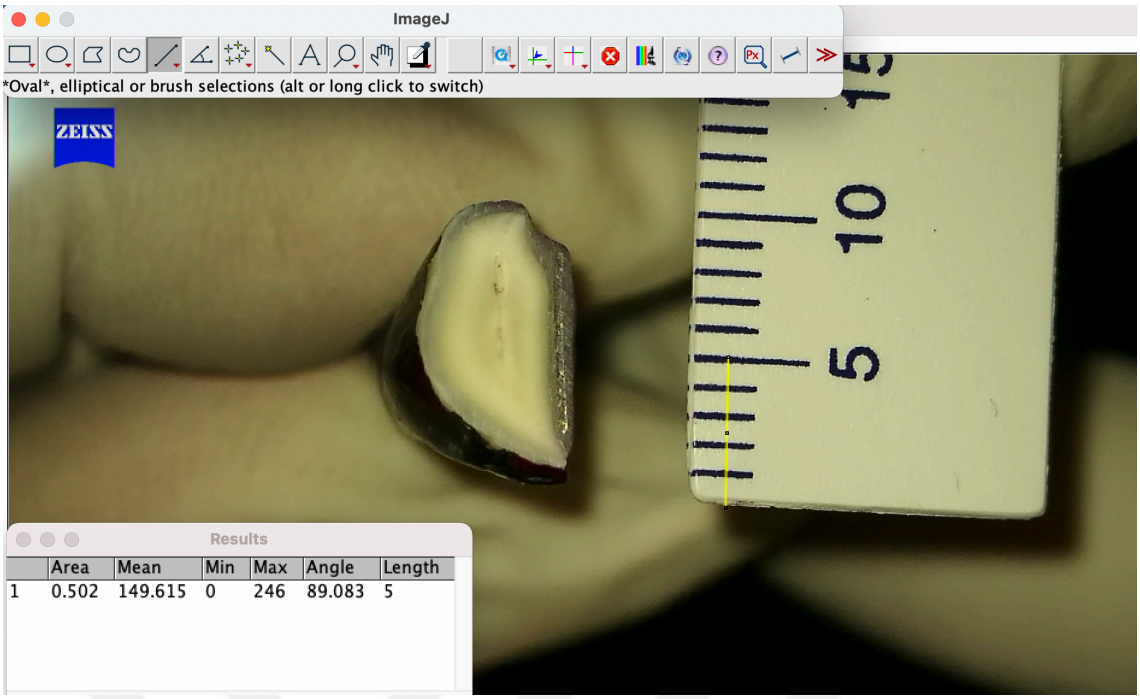

Figure 3.28 Measurements with ImageJ 1.46r software

3.10. Statistical Analysis

For this study, statistical analysis were be measured with NCSS(Number Cruncher Statistical System) 2007 Statistical Software (Utah,USA). In the evaluation of the data, descriptive statistical methods (mean, standard deviation, median, interquartil range), as well as the distribution of variables by Shapiro - Wilk normality test was examined. One-way analysis of variance in multiple-group comparisons of normally distributed variables, Tukey multiple comparison test in subgroup comparisons, independent t-test in comparison of binary groups, Dunn's multiple comparison test in subgroup comparisons of Kruskal Wallis Test, in comparison of binary groups Mann Whitney U test and chi-square test were used to compare qualitative data. Results were be evaluated at the level of significance $p < 0.05$.

4. RESULTS

Microleakage scores of different orthodontic retainers under simulated gastroesophageal reflux disease at the mesial and distal side in enamel-adhesive interface, bonded with Filtek Ultimate Flowable and Transbond LR using Elipar S10 light curing unit, with or without previous air abrasion of the enamel are shown in the Table 4.1 and Figure 4.1.

Table 4.1 Comparison of microleakage scores at the mesial and distal margins among all groups

Retainer Type	Adhesive System	Air Abrasion	pH	Mesial	Distal	p
			pH 7	1,735±0,592	1,700±0,452	0,889
		AirAbrasion (-)	**pH 1.5**	2,665±0,880	2,449±1,374	0,696
			pH 7	0,562±0,219	0,522±0,149	0,660
		AirAbrasion (+)	**pH 1.5**	1,934±0,512	1,934±0,365	0,998
	Flowable		**pH 7**	1,022±0,705	1,088±0,525	0,825
		AirAbrasion (-)	**pH 1.5**	2,180±0,357	2,160±0,412	0,913
			pH 7	0,278±0,126	0,356±0,176	0,297
		AirAbrasion (+)	**pH 1.5**	1,868±0,449	1,764±0,554	0,667
Direct	**LR**		**pH 7**	1,859±0,325	1,706±0,471	0,432
		AirAbrasion (-)	**pH 1.5**	2,614±0,500	2,574±0,359	0,848
Indirect	**Flowable**		**pH**	0,544±0,135	0,644±0,194	0,223

		7			
	AirAbrasion	**pH**			
	(+)	**1.5**	1,925±0,555	1,950±0,464	0,918
		pH			
		7	1,125±0,356	1,147±0,224	0,879
	AirAbrasion	**pH**			
	(-)	**1.5**	2,153±0,392	2,255±0,391	0,588
		pH			
		7	0,357±0,098	0,392±0,147	0,565
	AirAbrasion	**pH**			
LR	**(+)**	**1.5**	1,887±0,414	1,826±0,414	0,756

When the microleakage scores of each of the 16 groups are analyzed at both mesial and distal margins, there is no statistically significant difference between mesial or distal microleakage scores in any of the groups at the $p<0.05$ significance level. Since there is no statistically significant difference between the mesial and distal microleakage scores, they were combined in the following measurements to obtain a larger sample size.

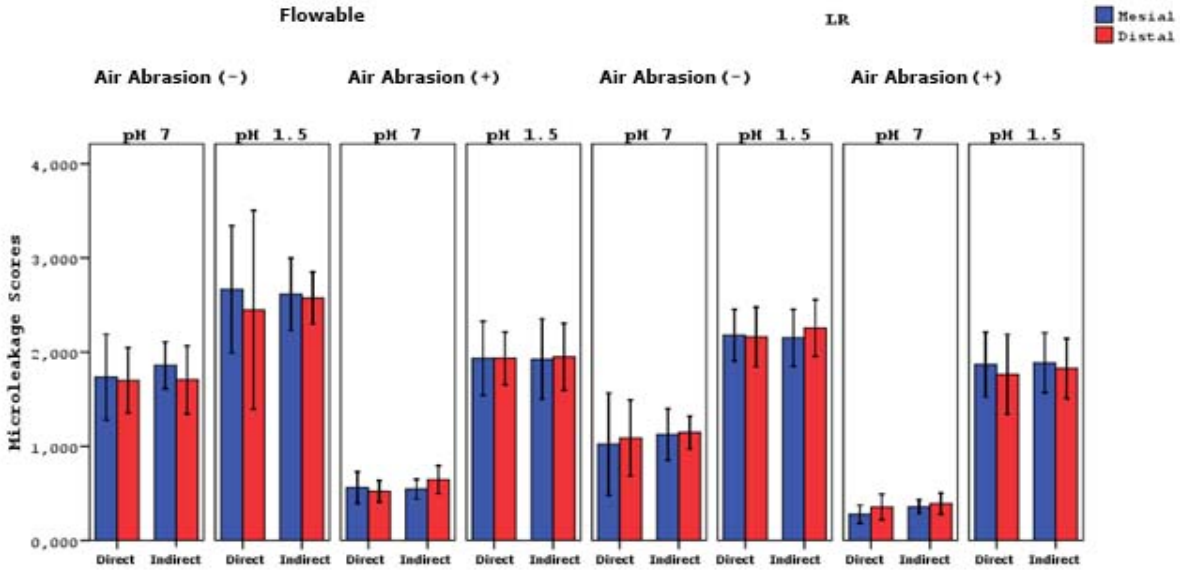

Figure 4.1 Microleakage scores at the mesial and distal margins of all groups shown in graphic

The effect of different orthodontic retainer wires on microleakage scores with different adhesive systems, which are exposed to different pH values with or without air abrasion preconditioning are shown in Table 4.2 and Figure 4.2.

Table 4.2 Comparison of the effect of different orthodontic retainer wires on microleakage scores among all groups

Adhesive System	Air Abrasion	pH	Direct	İndirect	p
Flowable	Air Abrasion (-)	pH 7	1,718±0,511	1,782±0,400	0,675
		pH 1.5	2,557±1,125	2,594±0,423	0,896
	Air Abrasion (+)	pH 7	0,542±0,183	0,594±0,170	0,380
		pH 1.5	1,934±0,431	1,937±0,496	0,982
LR	Air Abrasion (-)	pH 7	1,055±0,604	1,136±0,289	0,612
		pH 1.5	2,170±0,374	2,204±0,383	0,789
	Air Abrasion (+)	pH 7	0,317±0,154	0,374±0,122	0,221
		pH 1.5	1,816±0,492	1,857±0,403	0,787

Regarding the analysis, there is no statistically significant difference between two different orthodontic retainer types microleakage scores in any of the groups at the $p<0.05$.

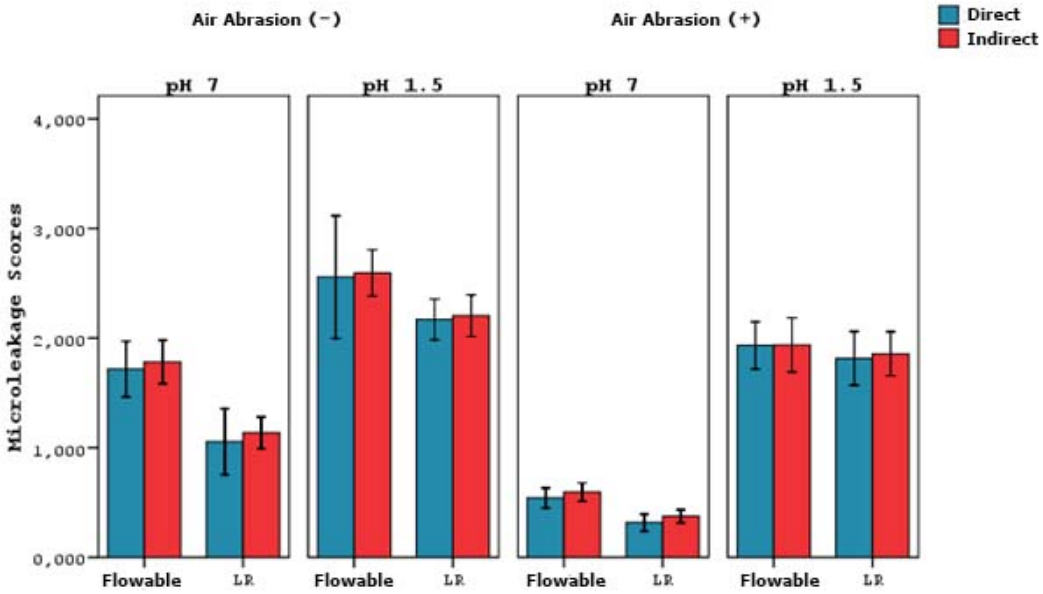

Figure 4.2 Microleakage scores of different orthodontic retainer wires regarding all groups shown in graphic

The effect of different pH values, defining gastroesophageal reflux disease, on microleakage with different adhesive systems and different orthodontic retainers with or without previous air abrasion of the enamel are shown in the Table 4.3 and Figure 4.3.

Table 4.3 Comparison of the effect of different pH values on microleakage scores among all groups

Orthodontic Retainer	Adhesive System	Air Abrasion	pH 7	pH 1.5	p
Direct	Flowable	**Air Abrasion (-)**	1,718±0,511	2,557±1,125	**0,007**
		Air Abrasion (+)	0,542±0,183	1,934±0,431	**0,0001**
	LR	**Air Abrasion (-)**	1,055±0,604	2,170±0,374	**0,0001**
		Air Abrasion (+)	0,317±0,154	1,816±0,492	**0,0001**
Indirect	Flowable	**Air Abrasion (-)**	1,782±0,400	2,594±0,423	**0,0001**
		Air Abrasion (+)	0,594±0,170	1,937±0,496	**0,0001**
	LR	**Air Abrasion (-)**	1,136±0,289	2,204±0,383	**0,0001**
		Air Abrasion (+)	0,374±0,122	1,857±0,403	**0,0001**

With both retainer types used in the study, and with the both adhesive systems, regardless of the previous air abrasion of the enamel, there has been found a statistically significant difference of the microleakage scores with different pH values at the $p<0.05$ significance level. Among all groups, the microleakage score of the group immersed in the solution of pH 1.5 showed statistically significantly higher result than the group which is exposed to a solution of pH 7 at the $p<0.05$ significance level.

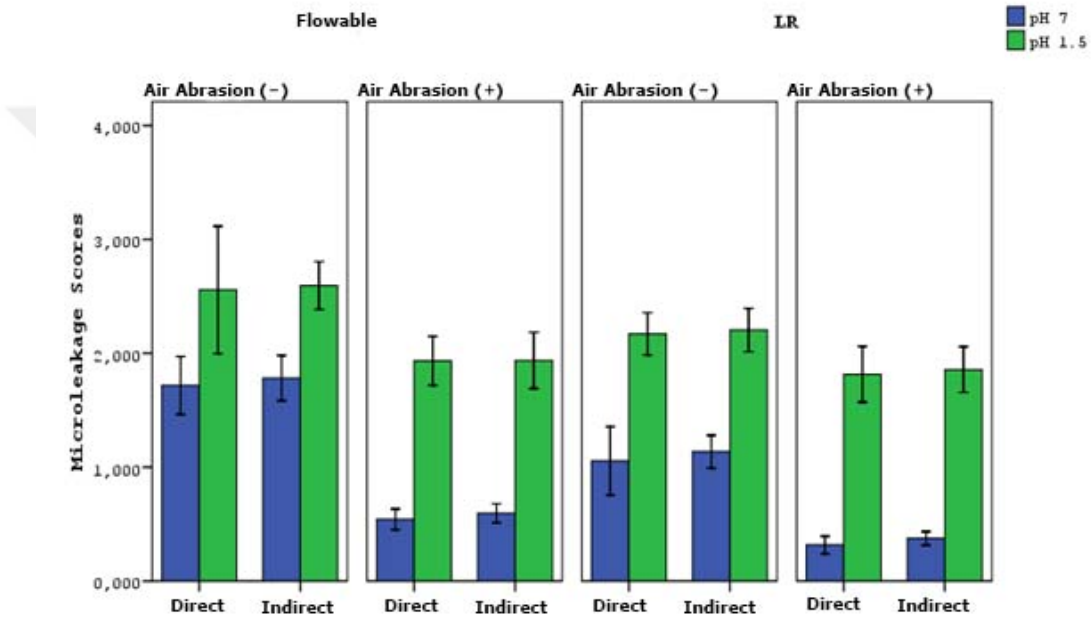

Figure 4.3 Microleakage scores of different pH values regarding all groups shown in graphic

The effect of air abrasion on microleakage scores with different adhesive systems, different orthodontic retainers and within an immersion to different pH values are shown in the Table 4.4 and Figure 4.4.

Table 4.4 Comparison of the effect of previous air abrasion of the enamel on microleakage scores among all groups

Orthodontic Retainer	Adhesive System	pH	Air Abrasion (-)	Air Abrasion (+)	p
Direct	Flowable	**pH 7**	1,718±0,511	0,542±0,183	**0,0001**
		pH 1.5	2,557±1,125	1,934±0,431	**0,035**
	LR	**pH 7**	1,055±0,604	0,317±0,154	**0,0001**
		pH 1.5	2,170±0,374	1,816±0,492	**0,02**
Indirect	Flowable	**pH 7**	1,782±0,400	0,594±0,170	**0,0001**
		pH 1.5	2,594±0,423	1,937±0,496	**0,0001**
	LR	**pH 7**	1,136±0,289	0,374±0,122	**0,0001**
		pH 1.5	2,204±0,383	1,857±0,403	**0,012**

With both retainer types used in the study, and with the both adhesive systems, regardless different pH values, there has been found a statistically significant difference of the microleakage scores with previous air abrasion of the enamel at the $p<0.05$ significance level. Among all groups, the microleakage score of the group which has not gone under a previous air abrasion of the enamel showed a statistically significantly higher result than the group which has undergone a previous air abrasion of the enamel at the $p<0.05$ significance level.

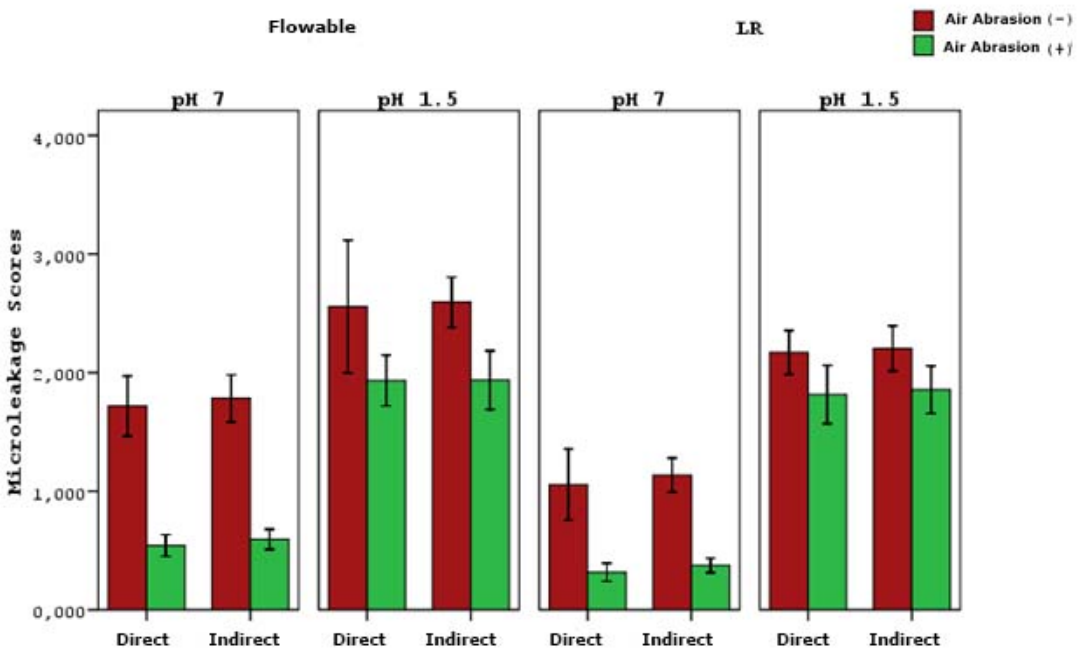

Figure 4.4 Microleakage scores with and without previously air abrasion method of the enamel regarding all groups shown in graphic

The effect of different adhesive systems on microleakage scores with different orthodontic retainers, within an immersion to different pH values and with or without previously air abrasion to the enamel surface are shown in the Table 4.5 and Figure 4.5.

Table 4.5 Comparison of the effect of different adhesive systems on microleakage scores among all groups

Orthodontic Retainer	**Air Abrasion**	**pH**	**Flowable**	**LR**	**p**
Direct	**Air Abrasion (-)**	**pH 7**	1,718±0,511	1,055±0,604	**0,001**
		pH 1.5	2,557±1,125	2,170±0,374	0,175
	Air Abrasion (+)	**pH 7**	0,542±0,183	0,317±0,154	**0,0001**
		pH 1.5	1,934±0,431	1,816±0,492	0,448
Indirect	**Air Abrasion (-)**	**pH 7**	1,782±0,400	1,136±0,289	**0,0001**
		pH 1.5	2,594±1,423	2,204±0,383	0,180
	Air Abrasion (+)	**pH 7**	0,594±0,170	0,374±0,122	**0,0001**
		pH 1.5	1,937±0,496	1,857±0,403	0,595

It was found that all of the groups which have undergone to an immersion to pH of 1.5, have not shown any statistically significant results with their microleakage scores regardless of the retainer type used, previous air abrasion of the enamel or the adhesive type used for bonding. The other 4 groups which have undergone to an immersion to pH of 7, have shown statistically significant results with their microleakage scores.

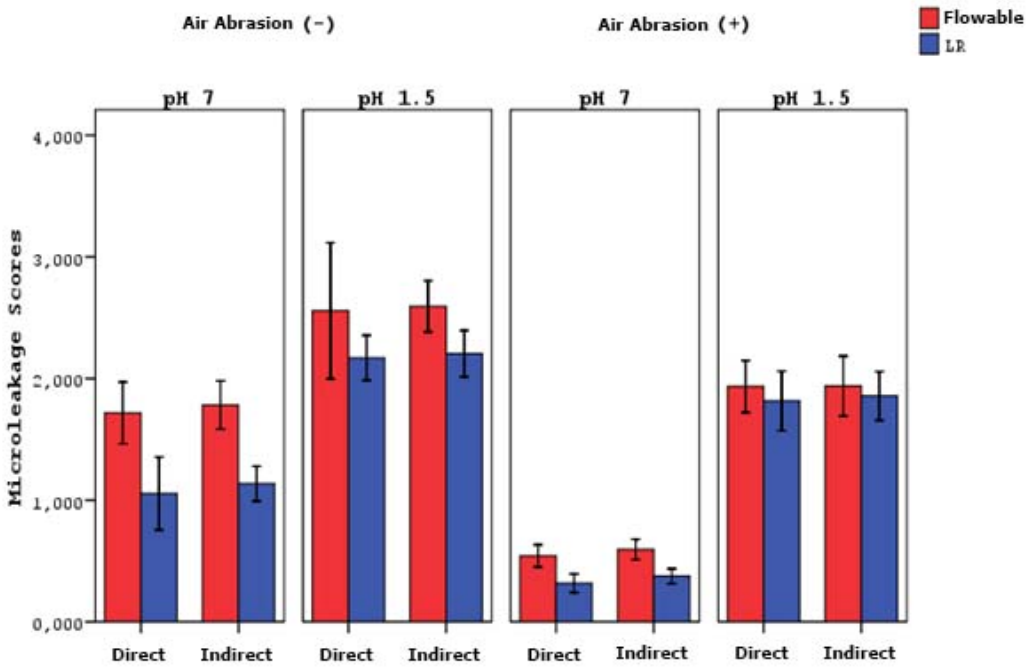

Figure 4.5 Microleakage scores of different adhesive systems regarding all groups shown in graphic

5. DISCUSSION

The retention protocol is the longest and the most important phase of the orthodontic treatment. Every orthodontist aims to sustain the final position of the teeth that they reached at the end of the treatment for a life time. For these reasons there are some retention protocols which have mentioned. Since the patient has usually undergone to approximately 1.5 - 2 years of orthodontic treatment, it should not be missed that at the end of the treatment the patient is usually bored and not willing to participate any more responsibilities with their retention protocol. Fixed orthodontic retainers are retainers that does not need any patient compliance during the retention phase. Regarding the cases' situation, these retainers stay in the mouth for a longtime. When a dental material stays in the mouth for a longtime, there are some issues that we have to be careful about, and one of them is microleakage.

The main reason for the restorative material to fail is the marginal leakage. Through the micro gap between the cavity wall and the restorative material, there occurs an air passage which includes bacteria, oral fluids, molecules and ions. Even though this process takes time, the fail is inevitable. Taking in consideration of this, there is a high risk of secondary caries.

Some causes of the microleakage can be listed as the difference in thermal expansion coefficient between the filling material used and the dental tissues, difference in thermal expansion coefficient between the enamel and dentin, shrinkage of the filling material used during polymerization, wear of the filling surface over time, elastic deformation of the filling material by occlusal forces, failure to comply with the necessary rules and the dentists carelessness during the restorative material placement.

Achieving an optimal marginal integrity between the enamel and the retainer is of the most important issue due to its impact on both the bond strength of the retainer and the establishment of a secure seal. This seal plays a key role in preventing the migration of oral fluid and bacteria, thereby minimizing the occurrence of secondary caries formation[33,190].

Therefore, finding the adequate retainer bonding environment which is less likely to cause a microleakage, is an important step in the development of orthodontics. In our study, microleakage scores of different orthodontic retainers with different adhesive systems under simulated gastroesophageal reflux disease (GERD) was evaluated.

The current researches uses bovine incisors as an alternative to human premolars in order to assess microleakage. Due to advancements in the field of preventative and restorative dentistry, collecting a substantial quantity of human premolars has become challenging[21]. Additionally, there are potential risks of infection and ethical considerations while handling human tissues[23]. Hence, researchers often prioritize the use of bovine teeth due to their plentiful availability, consistent composition, and extensive defect-free surfaces, making them an optimal selection for adhesion study designs[30]. Moreover, the surface morphology of human premolars may be attributed to variations in the adhesive layer thickness, which arise from differences in the surface curvature angles of human premolars. Bovine incisor teeth often provide a substantial and flat area suitable for bonding a bracket or a retainer, but human premolars exhibit more diversity in terms of their form and buccal surface angles[21].

The chemical composition and physical features of human and bovine enamel exhibit similarities, as shown by the literature study conducted by Yassen et al.[29]. Reeves et al.[191] conducted a study to assess microleakage in human and bovine teeth using three distinct bonding methods. Their findings indicated that there were no statistically significant variations seen in the microleakage properties between human and bovine teeth. In the same way, Almeida et al.[35] and Fitchie et al.[36] reached the same conclusion in their respective studies, which examined several adhesive systems. Their findings indicate that there were no statistically significant disparities seen between human and bovine substrates in relation to microleakage. Consequently, the research used bovine incisor teeth to assess microleakage.

Following the assessment of the existing literature, it was seen that a range of storage solutions have been used in researches involving teeth. These solutions include thymol solutions[192–194], chloramine solutions[32,33,55], saline solutions[195], and distilled water[64,171,172,196–199]. Additionally, it should be noted that in numerous studies, [200] it is not

precisely mentioned. The literature study revealed a lack of standardization regarding the storage techniques used for collected teeth. Given its widespread use and its ability to maintain the integrity of enamel structure and bonding properties with adhesives, distilled water was selected as the optimal solution for our investigation. In order to inhibit the proliferation of microorganisms, the distilled water was replaced on a daily basis.

Based on existing research, it is advised to eliminate the plaque and pellicle layer present on the enamel surface to avoid their interference with the ideal acid etching of the enamel surface prior to bonding[201]. In addition, it is standard for manufacturers to suggest the polishing of enamel surfaces prior to the application of adhesive. In our investigation, the teeth were subjected to a polishing procedure using pumice for a duration of 10 seconds, followed by a rinsing step with water lasting 15 seconds.

One of the factors assessed in our investigation is air abrasion. Air abrasion is used as a method of macro etching for enamel preparation. The roughening of the enamel surface is induced by the interplay between the size of aluminum oxide particles and the air pressure in this particular procedure[202]. According to Chan et al.[203], the use of direct air abrasion on enamel has been proposed as a means to remove particles and improve surface roughness, hence facilitating the creation of an adequate bonding area. Multiple researchers have conducted observations indicating that air abrasion alone is insufficient for eliminating the acid etching process. However, the use of both air abrasion and acid etching treatments in combination has shown potential for improved adherence to dental substrate[140,204,205]. In light of recent research findings, our investigation included the application of air abrasion treatment on enamel surfaces prior to acid etching, with the aim of examining the impact of air abrasion on microleakage patterns.

Another element that was assessed in our research is the variation in adhesive systems. One of the primary objectives of this study was to examine the potential influence of adhesive system type on the microleakage characteristics of the enamel-adhesive complex. Various composites have been documented for utilization in conjunction with this methodology, encompassing both restorative and orthodontic bonding agents. Numerous manufacturers have undertaken the development of adhesives specifically designed for the purpose of bonding lingual retainers. Transbond LR is a light-cured composite material that is highly filled and developed specifically for the adhesion of lingual retainers[206]. These manufacturers claim that their adhesives provide the advantages of simplified application

procedures and superior handling properties. When endurance and durability are desired, it is suggested that these light-cured resins with high fillings are a more favorable option[206]. The use of flowable composites, first developed to enhance the resin content of conventional microfilled composites in restorative dentistry, has been proposed as a viable option for the bonding of lingual retainers[152]. These composites are purported to offer benefits in the field of restorative dentistry due to their characteristics. They eliminate the need for manual mixing, as they can be directly applied using needle tips on the application syringes, ensuring precise placement. Additionally, these composites do not possess a sticky consistency, and their flow properties direct the material towards the bulk of the restoration rather than away from it. Consequently, the need for trimming and polishing is eliminated, resulting in reduced chair time[152].

Eventhough Transbond XT is often recognized as the "gold standard" composite resin for orthodontic bonding[207] and is widely used as an adhesive in the field of orthodontics, many researchers examined the microleakage of the Transbond XT and our goal is to compare flowable nanocomposite Filtek Ultimate and Transbond LR (light cure) in our study. The etching step for the both adhesive systems are %37 phosphoric acid. The literature suggests that a duration of 15 to 30 seconds of etching with 35-37% phosphoric acid has been found to provide satisfactory bonding values[201]. In our investigation, a 15-second application of acid etch was used. Gel form phosphoric acid was selected due to its ease of control.

The other factor which we assessed in our investigation is the orthodontic retainer type. To achieve a better durability and success, the type of the retainer is also an important factor. For more than 20 years flexible spiral wires are common. These wires usually compose of small diameter size of multistranded stainless steel wires with a diameter around 0.015 inch and 0.032 inch. They can either be round or rectangular with 3 to 6 fine strands braided or arranged coaxially. In our study one of the bonded orthodontic retainer type that we used is a multistranded round stainless steel 6 stranded wire with a diameter of 0.0215 inch. This wire is used with the indirect bonding technique in our clinic which requires an extra chair time for the impression. The other bonded orthodontic retainer which we used is a multistranded rectangular stainless steel braided wire with a diameter of 0.010 inch * 0.028 inch. This wire is used in our clinic with the direct bonding technique which does not require an extra chairtime but necessitates a careful bonding process.

Thermal cycling is a technique used to replicate the fluctuations in temperature observed inside the oral cavity, therefore inducing sequential thermal stresses at the interfaces between enamel and adhesive, as well as between bracket and adhesive. Researchers use this methodology in in-vitro investigations to assess the microleakage or adhesive bond strength in a way that closely aligns with clinical relevance[33,172,208]. Nevertheless, several studies have shown that there is no correlation between an elevated thermal cycle count and an augmented occurrence of microleakage in dental restorations[209]. A research was conducted by Bedran-de-Castro et al.[210] to assess the microleakage and shear bond strength of restorations on bovine incisors after exposure to 2000 heat cycles. The researchers observed that thermocycling did not have a statistically significant impact on either microleakage or shear bond strength. In a similar vein, Kubo et al.[211] conducted a research on bovine incisors to assess the extent of microleakage shown by self-etching primers after 5000 heat cycles. Additionally, it was revealed that the marginal integrity was unchanged during thermocycling. Consequently, thermocycling was not used in our investigation.

Several methodologies have been proposed for the assessment of microleakage around adhesives. The approach that is often favored due to its convenience and widespread use involves subjecting samples to a dye solution, followed by microscopic examination of the materials subsequent to cross sectioning[176]. The dye penetration method is a reliable technique for assessing microleakage areas using visible light. This method offers several advantages, including its efficiency in providing quick and straightforward measurements. Moreover, it is a cost-effective approach that does not pose any toxicity risks or induce chemical reactions with dental tissues. Additionally, the dye penetration method serves as a suitable evaluation method for comparing the microleakage behavior of various orthodontic bonding methods[185,195]. Hence, the dye penetration technique was selected as the method of choice in our investigation to assess the extent of microleakage in the bonded specimens. The most often cited strategy in past research studies involves using a 0.5% basic fuchsine solution for a length of 24 hours to conduct dye penetration analysis[172,192,207,212]. In our investigation, the application of dye penetration using a 0.5% basic fuchsine solution for a duration of 24 hours was used.

The current worldwide prevalence and widespread intake of acidic beverages are expected to contribute to an increased incidence of erosion-related issues among individuals. Individuals may also encounter similar issues as a result of other inherent factors, such as

gastroesophageal reflux disease or bulimia nervosa. Dental erosion is characterized as the permanent degradation of dental hard tissue resulting from a chemical mechanism, independent of microbial activity[213]. Dental erosion has the potential to cause harm not just to enamel, but also to several types of dental restorations. In the event of microleakage occurring at the interface between the dental restoration and the tooth structure, the erosive material has the potential to disintegrate, hence facilitating the infiltration of acid ions into the margin at a significant depth. The interaction between external factors and enamel may result in the development of secondary caries, leading to the penetration of dentin and subsequent occurrence of hypersensitivity inside the cavity.

In our study, pH values were selected as 1.5 for simulated GERD and pH 7.0 for artificial saliva. The same formulation for the artificial gastric fluid was used in the study of Cengiz et al.[186]. In other study, Derceli et al[214] simulated the reflux at pH 2.0 level. The selection of these specific acidic pH values in our research was based on their representation of varying degrees of acidity seen in the gastric refluxate inside the oral environment, as also shown in the study conducted by Mann et al.[188]. In this investigation, a control group was established using artificial saliva to replicate oral settings that are free from gastroesophageal reflux disease (GERD). The formulation of the artificial saliva was adjusted based on the guidelines provided by Preetha and Banerjee in their publication[189]. Numerous formulations of artificial saliva have been documented in the existing literature. Furthermore, there exists a dearth of guidance regarding the standardization of saliva type for use in in-vitro procedures aimed at investigating erosive phenomena[215]. In our investigation, the inclusion of pepsin in simulated gastric solutions was motivated by its potential diagnostic significance in saliva, as well as the detection of active pepsin in the stomach refluxate, which often exhibits a pH below 4. Similarly, Aytaç et al.[216] conducted an in-vitro examination to assess the influence of artificial stomach fluid on enamel surface roughness, while Cengiz et al.[186] investigated the effects of simulated gastric solution on laboratory-processed composites. Both studies used the same formulation as the present work. In contrast, Backer et al. [217] used a pepsin-free simulated gastroesophageal reflux disease (GERD) medium in their investigation on the effects of simulated gastric solution on CAD/CAM resin composites. The diagnostic utility of pepsin remains a topic of debate in the existing body of literature.

In the present investigation, the material variable was maintained at a constant level, while the variables of time and pH were investigated in order to more accurately

replicate the conditions of gastroesophageal reflux disease (GERD). In the case of these individuals, there is intermittent contact between hydrochloric acid and the oral cavity, lasting just a few seconds, and occurring many times during the day[214]. For this reason, the immersion regimes were carefully carried out for 8 days; each immersion lasting for five minutes. The regime was distributed over a 12-hour period. Before and after each immersion, the restorations were copiously rinsed in 0.1 M phosphate buffered saline (PBS pH 7.2). When not exposed to the immersion regime, they were stored in deionized water at room temperature. In literature different exposure times were observed. Maganur et al.[218] applied the same methodology with us and carried this part of the experiment for 8 days,5 times a day during 5 minutes for medium immersion, 8 days once a day during 5 minutes for low immersion and 8 days, 10 times a day during 5 minutes for high immersion. Since we already had 16 groups for our study, we did not seperated our groups for low, medium or high immersion groups and we only used the medium immersion to take the average of them. It is assumed that a person with medium severity of GERD undergoes a reflux attack aproximately 5 times a day. For this reason, we developped our methodology as mentioned. Huang et al.[219] conducted an experiment in which the new and recycled brackets were subjected to varying pH levels for a duration of 12 weeks. In other study, Jang et al.[220] used various stainless steel (SS) brackets, whereas Kang et al.[221] employed different titanium-based (Ti-based) brackets. With both of these studies, the brackets were subjected to acetic sodium fluoride (NaF) solutions with varying pH levels for a duration of three days. Erdoğan[222] subjected the silver soldered and laser welded samples to immersion in several kinds of mouthwashes for a duration of 24 hours. In the study conducted by Mikulewicz et al.[223], the samples were immersed in artificial saliva for a duration of 30 days. Conversely, Gürsoy et al.[224] and Danaei et al.[225] extended the immersion period to 45 days in their respective studies. Achieving standardization of time poses significant challenges and is considered very unlikely due to the inherent variability in symptom frequency and severity across individual patients. Furthermore, in conjunction with the previously mentioned difficulties encountered in in-vitro investigations, it is worth noting that there is a lack of universally accepted protocols pertaining to the duration of immersion in various solutions.

In this section, an evaluation of the data obtained from our research will be presented, using the materials and procedures previously described.

When the microleakage scores of the 16 groups of our study was examined at both mesial and distal margins there was found no statistically significant difference in any of the groups. Since there were no statistically significant difference, they were combined to obtain a larger sample size. It was seen the same measurement type with the research of Yagcı et al.[132]. They searched the microleakage between composite/wire and composite/enamel interfaces of flexible spiral wire reainers with direct versus indirect application methods. As same as our study, since there was no difference between the mesial and distal microleakage scores, the score for each group was obtained by measuring the mean of them. Differently from our study, they used a electronic digital calliper to measure the microleakage score while with our study we used a surgical microscope (ZEISS, Oberkochen, Germany). Both of the materials are microlekage evaluation methods as mentioned before. As a conclusion, it was found that there were not any statistically significant results between the amount of microleakage of the bonding method (direct vs. indirect) at enamel-composite-wire complex. There were also found no statistically significant results between the enamel-composite and wire-composite interfaces.

With the study of Nimbalkar-Patil et al.[226] microleakage between the wires were evaluated at two sites (mesial and distal) and at two interfaces (enamel-composite and wire composite). Their study was designed to find the difference of microleakage of 2 lingual retainers bonded with three different lingual retainer composites. As seen in the results, they found that at both enamel composite and wire composite interfaces, least microleakage result was seen with Transbond LR followed by Concise Orthodontic and Transbond XT. For both of the wires, when the microleakage values were compared at both enamel composite and wire composite interfaces, there were no statistically significant results and two interfaces were found more or less equal.

Also with the research of Uysal et al.[227] different lingual retainer composites and microleakage between enamel-composite and wire composite interfaces were evaluated. Since there wasn't statistically significant result of microleakage between the mesial and distal interfaces, the scores were also pooled in this study for the mesial and distal interfaces and the microleakage scores were calculated by getting the mean scores. There were also no difference between the enamel-composite and wire-composite interfaces ($p>0.05$). Eventhough most of the studies compared Concise Orthodontic and Transbond

XT as a composite type for lingual retainer bonding, and commonly prefered these two resins in lingual retainer studies, Transbond XT was chosen since it is a light cured adhesive and the concise orthodontic is chemical cured adhesive. Within time, Transbond LR is introduced to the market as a specially manufactured composite for lingual retainers and for this reason it is one of the adhesives that we used in our study. Lately, flowable composites are slated for lingual retainer bonding since they allow direct composite placement with an application syringe and since they do not require any trimming and polshing which reduces chair time. It is interesting that this material was not studied depthly in the literature. The study of Uysal et al. compared the microleakage scores of Transbond XT, Transbond LR and Venus Flow. They found that there were no significant difference in the microleakage among these three different composite adhesives chosen both at the enamel-composite and wire-composite interfaces. With our study, we found that there is statistically significant result of the microleakage scores between the adhesive types which are immersed to a solution of pH 7. This difference may be the result of the importance of pH with the microleakage. We have already seen that regardless of the other variables, pH indicates an important factor when microleakage is evaluated. It is already found that there is statistically significant difference between the microleakage scores of different pH immersion regimes and samples which have immersed to a solution of pH 1.5 showed higher microleakage scores with all of the groups. Regarding the huge effect of the pH, we can say that since pH 1.5 exhibited high microleakage score among all groups, the effect of pH is a lot excessive than the adhesive difference which explains that samples which have immersed to pH 1.5 didn't show any statistically significant results between the adhesive types. Regarding this effect of the pH value, the pH 7 which is the normal condition shows clearly that there is statistically significant difference between the microleakage scores with different adhesive types. It is seen that fixed retainers bonded with Transbond LR, regardless of the previous air abrasion of the enamel or the retainer type shows less microleakage score than the fixed retainers bonded with 3M Filtek Ultimate Flowable composite. The reason for this may be the filler sizes of the resin composites. 3M Filtek Ultimate Flowable composite has lower filler load (by weight) or smaller particle size compared to Transbond LR. While 3M Filtek Flowable Composites total average particle size is of 0.6 to 10 μm, the total inorganic filler loading is approximately 65% by weight. On the other hand Transbond LR has approximately same particle sized but higher filler content which is 75-85% by weight[226]. Tancan et al.[132] found the same results with us in their study which compares the microleakage

scores of 3 different composites used also for retainer bonding procedure. Eventhough their null hypotheises was that there is no difference between the microleakage scores of the composites used, they found that the flowable composite showed the highest microleakage score while Transbond XT and Transbond LR showed significantly lower and comparable results. As a result they also explained these findings with the lower filler load and smaller particle size of the flowable composite and as a result claimed that flowable composites may not be appropriate for bonding flexible spiral wire retainers.

Regarding that most of the studies designed to evaluate the microleakage found no difference between the enamel composite and wire composite interfaces, we designed our study not to base on different interfaces but to base on other variables since it enlarges out study group number. Polymerization shrinkage of the adhesive material may create micro gaps between the adhesive material and the enamel surface which may cause the formation of microleakage. Since in restorative dentistry, the microleakage is a phenomenon that promotes the passage of microorganisms and fluids from the oral cavity into the interface between the enamel and adhesive, facilitated by the creation of gaps[170], with our study we focued to measure the microleakage from the enamel composite interface and for this reason we covered the retainer wire with the composite to eliminate the effects caused by the gap between the retainer composite interface.

Focusing on the different retainer types choosed in studies, Nimbalkar-Patil et al.[226] used two different wires; a 0.036 inch hard round ss wire and 0.0175 inch multistanded wire. With our study we wanted to evaluate the difference between the wires that we use in our clinic. Since we don't use hard ss wires which enables the phsiologic movement of the teeth, we just used the multistranded wires and we wanted to evaluate the difference of a round multistranded wire and a rectangular braided multistranded wire. Fortunately, the results of Nimbalkar-Patil et al[226]. also found that the multistanded wire showed less microleakage which also indicates that our study design is reasonable. Kavousinejad et al.[228] also made a research about the comparison of microleakage of ribbon and twisted wire retainers bonded with 2 diffferent adhesives. They used 0.0175-inch twisted wire and 0.028×0.008-inch ribbon dead soft wire retainers as two types of retainers and Transbond XT and GC Ortho Connect Flow as adhesives. As a result they found that the type of adhesive affected the microleakage and that the microleakage score of the groups bonded with GC Ortho Connect Flow was higher than the groups which

were bonded with Transbond XT. On the other hand, type of the wire had no significant effect on microleakage. Regarding our analysis, we also found that there is no statistically significant difference between two different orthodontic retainer types microleakage scores in any of the groups at the $p<0.05$ significance level. Eventhough there is not any statistically significant difference of microleakage, among all groups the braided retainer wire which is bonded directly in the clinic after debonding procedure without taking any dental impression has shown lower microleakage scores than the multistranded round ss wire which is bonded usually indirectly with the requirement of a previous dental impression for the technician. The reason for this may be explained with "C factor" in dentistry which is the ratio of the surfaces bonded to the cavity to non-bonded surfaces in restorations. Which means that, as the surface area of the adhesive with the enamel increases, "C factor" also increases and as a result polymerization shrinkage and microleakage increases. Regarding the retainer wires surface, we can say that the round wire exhibits a larger bondable area to the enamel than the rectangular wire. This may be the reason why the indirect retainer wire exhibited higher microleakage score which is not statistically significant. With respect to this results we can not make any strict comment about the usage of both of the retainer wires since there isn't any statistically significant result and since the strength factor is also an important issue in retention which we have not measured in our research.

The other factor that we used in our study was the air abrasion procedure. We measured the effect of air abrasion on microleakage scores of different adhesive systems, different retainer types and with different pH valued environments. It was observed that among all groups, the microleakage score of the group which has not gone under a previous air abrasion of the enamel showed a statistically significantly higher result than the group which has undergone a previous air abrasion of the enamel at the $p<0.05$ significance level. Similarly to our study, Kofman et al.[229] made a research about microleakage of three sealants following conventional, bur and air-abrasion preparation. They found that air abrasion with acid etching provided significantly less microleakage than the other methods of preparation and concluded that the microleakage can mostly be prevented with a combination of mechanical air abrasion and chemical etching. The micromechanical bond between enamel and restorative material is formed by resin infiltration into enamel microporosities caused by acid conditioning, air abrasion, or self-etching priming substances. Inadequate sealing capacity can lead to the infiltration,

invasion, and accumulation of bacteria, thereby potentially causing secondary caries. Phosphoric acid etching of the enamel before applying resin restorative materials has been shown in multiple laboratory experiments to decrease microleakage and enhance bond strength. Similar, the air abrasive approach has been suggested as an efficient method for preparing enamel before the restoration. Baiping et al.[230] searched the effects of air abrasion and acid etching on the microleakage of preventive class I resin restorations and found out that the air abrasion should be combined with acid etching to reduce the microleakage. Moreover, they said that the microleakage scores were significantly higher in restorations which were placed after air abrasion with 27-μm compared to 50-μm aluminum oxide particles.

In contast to this study and ours, Kumar et al. found that the microleakage score is increased when the enamel is exposed to a previous air abrasion. The researchers attributed this outcome to the presence of subsurface micro fractures and cohesive failure inside the compromised enamel caused by prior air abrasion conditioning.[199]They also concluded that the air abrasion is a technique used for macroetching, which results in the formation of cavities and the creation of obtuse angular shapes. Consequently, it may lead to the formation of small openings and fractures in the enamel, which in turn leads to higher scores indicating the extent of leaking at a microscopic level. Nejad et al.[231] mentioned in their research that there is no statistically significant difference between the different types of enamel preparations. On the other hand, Bevilacqua et al.[145] searched the microleakage of a dental sealant with acid etching alone, air abrasion alone and combination of air abrasion + acid etching. They found that the combination of air abrasion and acid etching resulted in statistically significantly less microleakage than other groups. The reason why there are so many different results about this phenomenon may be the different types of adhesives used, different light curing units and tooth samples such as bovine incisors, human molars and premolars that were used in each study.

Lastly, with both retainer types used in the study, and with the both adhesive systems, regardless of the previous air abrasion of the enamel, there has been found a statistically significant difference of the microleakage scores with different pH values at the $p<0.05$ significance level. Among all groups, the microleakage score of the group immersed in the solution of pH 1.5 showed statistically significantly higher result than the group which is exposed to a solution of pH 7 at the $p<0.05$ significance level. Katge

et al.[218] also found the same results with us. They aimed to evaluate the microleakage of different adhesives immersed in soft drink and fresh fruit juice. The solutions used were coca cola, fresh fruit juice and water as a control group. It was found that the microleakage is increased in Cola group compared to fresh fruit juice and control groups. Cola which has a pH of 2.57 shows more acidic nature than the fruit juice and water and therefore, the acidic nature affects the integrity of the restoration with the enamel and increases the microleakage.

These findings may be our pathway when treating our patient. The anamnesis which includes the medical problems may also include the patients reflux and patients daily acidic beverage consumption. Taking in consideration of these results, clinically we can keep in mind that if the patients oral environment is exposed mainly to a low pH level, we can consider that the microleakage of our restoration will be increased and according to this, we can prepare the enamel surface with air abrasion prior to acid etching or we can prefer the appropriate adhesive with less microleakage score to achieve a better longlasting result. On the other hand, according to our results, that air abrasion should also be prefered if possible to achieve a better micromechanical bond between enamel and restorative material and to achieve less microleakage which therefore causes less failure of the retainer wire.

Like earlier in-vitro studies in the biomedical sciences, our study's design also has some limitations. Even though we tried to determine the oral cavity’s conditions, it is not possible due to supernumerary variables such as enzymes, minerals, corrosion due to occlusal forces or temperature changes in the oral cavity. To get more clinically significant outcomes, more in-vivo studies may be scheduled.

6. CONCLUSION

Based on the findings of this research, and considering the limitations of an in-vitro study, it is reasonable to conclude that:

1) There is no statistically significant difference between the microleakage scores of the mesial and distal margins in the enamel-adhesive interface, independent of the adhesive system, retainer type, pH level of the solution and air abrasion preconditioning.
2) There is no statistically significant difference between two different orthodontic retainer types microleakage scores in any of the groups.
3) Previous air abrasion of the enamel decreases the microleakage score.
4) As the pH of the solutions decreased (acidic environment increased), microleakage is increased.
5) Among all groups, the is no statistically significant difference of the microleakage score between the adhesive types which were immersed in the solution of pH 1.5. Conversely there was found a statistically significant difference of the microleakage score between the adhesive types which were immersed in the solution of pH 7.

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8. CURRICULUM VITAE

Kişisel Bilgiler

Adı	Simay	**Soyadı**	Yılmaz
Doğum Yeri		**Doğum Tarihi**	
Uyruğu		**TC Kimlik No**	
E-mail		**Tel**	

Öğrenim Durumu

Derece	**Alan**	**Mezun Olduğu Kurumun Adı**	**Mezuniyet Yılı**
Doktora	Ortodonti	Yeditepe Üniversitesi	2023
Yüksek Lisans	Diş Hekimliği	Yeditepe Üniversitesi	2017
Lisans	Diş Hekimliği	Yeditepe Üniversitesi	2017
Lise	Sayısal	Saint Joseph Fransız Lisesi	2012

[#] Başarılmış birden fazla sınav varsa(KPDS, ÜDS, TOEFL; EELTS vs), tüm sonuçlar yazılmalıdır

Bildiği Yabancı Dilleri	**Yabancı Dil Sınav Notu ([#])**
İngilizce	IELTS 7.5
Fransızca	B2

Bilgisayar Bilgisi

Program	**Kullanma becerisi**
Microsoft Office	İyi
Dolphin	İyi

*****Çok iyi, iyi, orta, zayıf olarak değerlendirin

Bilimsel Çalışmaları

SCI, SSCI, AHCI indekslerine giren dergilerde yayınlanan makaleler

Diğer dergilerde yayınlanan makaleler

Nalbantgil D(1), Burcu Nur Yılmaz R(1), Akın E(1), Erden MA(1), Yılmaz S(1), Özdemir F(2). Evaluation of the impact of interdisciplinary case-based courses in dental education on smile evaluation skills of undergraduate students. Turkish Journal of Orthodontics. 32(1):11-15. doi:10.5152/TurkJOrthod.2019.18012.

Uluslararası bilimsel toplantılarda sunulan ve bildiri kitabında (*Proceedings*) basılan bildiriler

1-5 Ekim 2016 XV. Uluslararası Türk Ortodonti Derneği Kongresi, Antalya - Sözlü Bildiri - Doğal ve Dijital Olarak Tasarlanmış Gülüşlerin Diş Hekimleri, Diş Hekimliği Öğrencileri ve Meslekten Olmayan Kişiler Tarafından Değerlendirilmesi – Nalbantgil D, Nur Yılmaz RB, Yılmaz S, Akın E, Erden MA
9-10 Eylül 2022 International Symposium of Lingual Orthodontic Society of Turkey, İstanbul – Sözlü Bildiri – Determintion of the criteeria weights of lingual and labial orthodontics with fuzzy mcdm -Akdağ H, Pınar C, Özgür G, Yılmaz S, Aktan D

Hakemli konferans/sempozyumların bildiri kitaplarında yer alan yayınlar

Diğer (Görev Aldığı Projeler/Sertifikaları/Ödülleri)

9-10 Eylül 2022 International Symposium of Lingual Orthodontic Society of Turkey, İstanbul Poster bildiri 2. lik ödülü – Orthodontic Treatment of the patient with severe crowding using customized lingual system -Yılmaz S, Aktan D