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Factors Contributing to Microleakage in Orthodontics: A Review of Literature

Lara Riyadh Al-banaa, Saif Sufyan Alsoufy, Ali R. Al-Khatib

Department of pedodontics, orthodontic and preventive Dentistry, College of Dentistry, University of Mosul

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***Correspondence:**

E-mail:
dr-lara-ra@uomosul.edu.iq

Abstract

Aims: Microleakage under brackets and bands are considered one of the common problems that occur during orthodontic treatments. The main objective of this paper was to review the available information regarding the factors contributing to microleakage in Orthodontics. Materials and Methods: Microleakage was defined, and reviewed and explained the factors contributing to microleakage in orthodontics. **Conclusion**: A considerable amount of research has been published concerning factors contributing to microleakage in orthodontics. this paper hopes to provide some information regarding this topic for both researchers and people working in clinical fields.

الخلاصة

الأهداف: يعتبر التسـرب المجهري تحت الحاصـرات والحلقات التقويمية واحدا من المشـاكل الشـائعة خلال العلاج التقويمي. الغرض الرئيسـي من هذا المقال مراجعة المعلومات المتوفرة المتعلقة بالعوامل المؤثرة على شـدة التسـرب المجهري في تقويم الاسنان. طريقة العمل: تعريف التسرب المجهري اضافة الى مراجعة وشرح العوامل المؤثرة عليه خلال العلاج التقويمي. الأستنتاج: ابحاث عديدة أنجزت في مجال التسرب المجهري المتعلق بتقويم الاسنان. هذا المقال يوفر بعض المعلومات التي تتعلق بالعاملين في مجال الابحاث اضافة الى العاملين بالمجال الطبي.

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INTRODUCTION

The term microleakage has been cited in the literature since 1912 by Harper, it can be defined as the migration of bacteria, liquids, chemicals through tooth-restorative material interface [1]

In orthodontics the polymerization shrinkage of adhesive materials during curing procedure produces a space between the enamel surface and adhesive materials which leads to ingress of bacteria, ions, fluids and toxic substances from the oral cavity and may lead to many problems associated with orthodontic treatment such as secondary caries, inflammation of the pulp, and White Spot Lesions (WSLs) .[2-4]

White Spot Lesions, defined as areas of localized enamel demineralization appear about 4 weeks after the beginning of orthodontic treatment, and become predictable about the first 6 months. [5-7] Moreover, microleakage may cause the failure of the orthodontic bracket bond by affecting the physical properties of orthodontic adhesive materials and forming a space between the enamel and the bracket and/or between the adhesive and the bracket. [8]

Komori et al. [9] reported that the RMGIC bond strength was approximately double when compared with conventional GICs used for bonding orthodontic brackets. In addition, Shankar et al. [10] suggested that RMGIC used for band cementation in primary molars had a lower microleakage score than conventional GIC at the band cement and enamel cement interfaces.

Williams et al. [11] examined the retention of orthodontic bands by conventional glass cement and PAMC. They found no significant differences in in vivo band failure rates between them. On the other hand, Shimazu et al. [12] concluded that a dual-cure resin-modified glass ionomer cement (RMGIC) has superior properties in terms of retentiveness, caries-preventive effect and microleakage than two types of light cure polyacid-modified composite resin (compomer cements). Conducting on previous studies performed, it was found that the transition from the banding of orthodontic attachments to bonding ones, orthodontics showed certain developments including the use of new adhesives and more efficient primers, designs of the bracket base, new bracket materials, light curing methods. They addressed their effects on microleakage and shear bond strength under bonded brackets and tube [13-14]

The aim of this paper was to provide information regarding the factors contributing to microleakage in Orthodontics.

- Factors Contributing to Microleakage in Orthodontics

1. Adhesive factors

A. Adhesive composition

Composite resins are composed of two main components: an inorganic mineral filler and an organic resin matrix. Flowable composites differ from the traditional composites by having the same particle size with lesser proportion of fillers to allow a higher proportion of resin, thus, decreasing the viscosity of the mixture [15]

Polymerization shrinkage of dental adhesive cause marginal gap and consequent marginal microleakage at adhesive-enamel interface and/or adhesive-bracket interface. The extent of shrinkage depends on the filler percentage, diluents and amount of monomer conversion of the composite resin.[16] Miyazaki et al [17] concluded that decreasing the amount of filler result in higher shrinkage polymerization. Kidd [18] reported that the greatest risk factor for the penetration of bacteria, liquid, ions and molecules over the cavity margins is the microleakage. and this may lead to clinical effects as secondary caries, marginal discoloration, sensitivity and lastly failure of restoration [19]

B. Type of adhesive system

Most of the studies conducted in this field were related to the addition of different bonding adhesives or modification of them and evaluate their effects on microleakage [20-22]. Various authors compared the effect between self-etching adhesive and acid-etch primers on micro-leakage. For example: Pakshir and Ajami [23] found non-significant differences in micro-leakage using Transbond XT primer. Self-etching prime (SEP) also have been reported to have low bonding strength [21,24]. Some authors concluded that there was no significant difference in bond strength between self-etching and the classic etching protocol.[25, 26]

Arhun et al. [27] compared between conventional systems and self-etching primers and found non-significant difference between them. On the other hand, Uysal et al. [20] showed higher microleakage scores of self-etching primers .

Sabzevari et al. [28] compared three different bonding techniques (Unite adhesive, Transbond XT, self-etching prime + Transbond XT), they found that bonding technique affect microleakage and it was more for the last group, but relatively similar results for Unite and Transbond XT groups. in contrast Atash et al. [29], found non-significant differences among six types of different adhesive systems. Bilen and Çokakoğlu [30] reported that orthodontic adhesive combined with primer has less microleakage value and adequate shear bond strength, so that it can be used safely during the bonding of ceramic and metal brackets instead of two- step total etch adhesives.

Fluoride released adhesive materials are recommended for orthodontic treatment. [31] The Resin Modified Glass Ionomer Adhesive (RMGIA) and compomer seem to offer better substitutes to the other types of resin adhesives due to the continuous fluoride release from them. Ramuglu et al. [32] study showed that conventional adhesive system had lower microleakage value than RMGI. RMGI desired where a strong initial fluoride release is needed in addition to a long-term effect. [33]

C. Thickness of the adhesive

An increase in the thickness of the adhesive material will adhere better to the enamel surface, but this will increase the surface area for plaque accumulation around the attachment base and so increasing the microleakage [34, 35]

D. Bonding technique

In1972, Silverman et al. [36] introduced indirect bonding method to place the brackets in a more precise manner by putting them on stone cast as the teeth can be visualized in three dimensions before moving to the mouth, this will result in a more accurate bonding of the brackets on the teeth and reduce the need to re-bond them at finishing stage of treatment. Indirect bonding technique has some advantages over the direct method: Avoid moisture contamination and accurate positioning of brackets increase patient comfort and reduce chair time [37,38]. Indirect bonding methods also have disadvantages including: an extra set of impressions are needed, more laboratory work, technique sensitivity, and the risk of adhesive flow to gingival margin of the teeth [38]

A study done by Zachrisson and Brobakken [39], compared between indirect and direct bonding techniques showed that direct method results in more closely fitted brackets to the tooth surface with less voids than the indirect method.

Moreover, Öztürk et al. [40, 41] and Yagci et al. [42], concluded that the type of bonding technique has no effect on microleakage and showed non-significant differences between them at the bracket –adhesive– enamel complex.

E. Modification of the adhesive by nanoparticles

Nanoparticles (NPs) are defined as insoluble particles smaller than100 nm in size. They have been used as antimicrobial agents in medicine and dentistry. [43] NPs are able to inhibit microbial activity of bacteria, viruses, and fungi as the growing strains of bacteria are less likely to produce resistance against NPs than conventional antibiotics [44]

NPs, have been added into orthodontic adhesives due to their biocidal capabilities to control the microbial adhesion around the brackets and bands, further more reduce demineralization and white spot lesion. Incorporating NPs to orthodontic adhesives and appliances should not affect the physical and chemical properties adversely, and decreasing clinical performance [45]

Hedayati and Frjood [46] study showed that the nanocomposite Filtek Z350 had higher microleakage value than the Transbond XT at gingival and occlusal of the brackets

On the other hand, Omidkhoda et al. (47) concluded that glass ionomer cement containing amorphous calcium phosphate (ACP) nanoparticles result in less microleakage at the cement-enamel interface than conventional glass ionomer. However, there was no significant difference in microleakage value between conventional glass ionomer and glass ionomer containing ACP in other sides.

Moreover, Heravi et al. (48) suggested that incorporation of caries preventive material: 1.56% w/w(CPP-ACP) Casein Phospho Peptide Amorphous Calcium Phosphate in to GIC had no effect on microleakage when compared with conventional GIC, so that they can be used for cementing orthodontic bands.

2. Bracket factors

A. Bracket material

The influence of the type of the material that the brackets manufactured from also affects microleakage. Metal brackets have been reported to produce more microleakage at the bracket-adhesive interface than ceramic brackets, which may result in WSLs and also affect clinical shear bond strength.(27)

Arikan et al. (8) reported that ceramic brackets have significantly less microleakage than metal brackets in both bracket-adhesive and enamel-adhesive interfaces when subjected to LED curing unit for adhesive polymerization. This difference is due to the fact that metallic brackets act as a barrier to transmit the light unlike the ceramic bracket, so prevent complete polymerization of the adhesives under them. On the other hand, Ramoglu et al. (32) compared between ceramic and metallic brackets and showed no significant differences between them.

Kim et al. (49) study showed no significant difference in microleakage scores between bracket system coated with the APC PLUS Adhesive and the bracket system coated by APC Flash-Free Adhesive after thermal cycling.

B. Bracket design

Chapra et al. (34) study, showed that bracket-adhesive interface has less bond strength than the adhesive-enamel interface as the coefficient expansion of metal brackets promotes gap formation between the adhesive and the bracket margins .

Conversely, other study showed further gap formation at the adhesive-enamel interface with higher bond strength at the bracket- adhesive interface (35). This depends alone on the bracket design, regardless of the substrate that appears to have a significant effect on microleakage and bond strength. Different surface features of the bracket designs produce different bonding environments. (5)

3. Enamel factors

A. Enamel preparation

There are several methods for enamel preparation before bonding: either self-etching (one step), by combining an acid etch with a primer, so decreasing procedure time; or “classic” etching, by applying acid etch into the enamel surface, followed by a primer and bonding agent. Another technique is the laser etching of the enamel, which is achieved at a specific duration and frequency. [29] Some studies compared between different methods of enamel preparations to investigate their effects on microleakage, Hamamci et al. [21], Al-hamidi and Al- khatib [51] showed that Er,Cr:YAG laser yielded significantly higher microleakage than phosphoric acid etching, this may be attributed to laser modules that create uneven and heterogeneous surface characteristics with micro cracks [52]

On the other hand Toodehzaeim et al. [53], found no differences between phosphoric acid etching and Er, Cr:YAG laser . Moosavi et al. [54] reported that application of NaF 2% decrease micro-leakage on hypomineralised enamel.

B. Enamel surfaces curvature

Enamel surfaces with different angles of curvature affect microleakage of bonded brackets and cemented band through their effect on the thickness of the adhesive layer [4]. Arhun et al. [27], found significant differences on microleakage scores between the gingival and occlusal margins of the brackets with more microleakage on the gingival side. Due to the curvature anatomy of the tooth surface, which may lead to thicker adhesive at the gingival margin, in addition to the direction of the light cure beam from the occlusal surface .[32]

4. light cure intensity

In recent years, many types of light cured adhesives were introduced and widely used in orthodontics. The advantages of these adhesives are: extended working time which allow for precise bracket positioning, high bond strength and minimal amount of oxygen inhibition. The major disadvantage of these adhesives is that microleakage at the tooth-adhesive interface resulted from shrinkage polymerization. [29]

Arikan et al. [8], Ulker et al. [16] concluded that no differences in microleakage scores among different intensities of LCU (PAC, LED, Halogen) at both bracket-adhesive and enamel-adhesive interface.

However, Uysal et al. study [55], compared between different intensities of curing units on microleakage under cemented bands, they found non-significant differences between them at the band-cement interface, while high light intensity had higher microleakage scores at the cement–enamel interface than low light intensity. On the other hand, some studies [56,57] showed that a low intensity light cure increase polymerization shrinkage and gap formation more than high intensity.

5. Miscellaneous factors

A. Temperature changes in oral cavity

Adhesive materials are usually exposed to temperature changes in the mouth. The enamel, the adhesive, and the bracket bases have different coefficients of thermal expansion which may apply more stress to the bonding adhesive strength due to recurrent contraction and expansion and may result in debonding of the orthodontic attachments. (58)

Thermocycling is a method used for the evaluation of bonding adhesives by exposing the restored teeth to temperature changes similar to those encountered intra-orally. This process will thermally stress the joint between the tooth and the restoration. The tooth structure and adhesive material differ in thermal expansion, this will result in different volumetric changes and causing weakness of the adhesive joint and consequent microleakage. (59) some studies have revealed that thermocycling significantly increases microleakage and reduces bond strength beneath the bond materials.(60,61)

B. The effect of contamination on microleakage

Some studies have evaluated the effect of contamination on microleakage. Kustarci and sokucu (62) found no significant differences in microleakage value among antimicrobial pretreatments including (chlorhexidine gluconate, potassium-titanyl-phosphate laser and Clearfil Protect Bond). Other studies acclaimed that consumption of soft drinks might increase microleakage under brackets and also reduce bond strength because exposure to soft drinks results in areas of enamel with loss of orthodontic adhesive. (63,64) Toodehzaeim et al. (65) found that saliva contamination associated with greater microleakage at the adhesive-enamel interface when compared to the adhesive-bracket interface.

C. The effect of bleaching on microleakage

Many studies showed that orthodontic treatment is associated with significant changes in tooth color. (66) Young patients having fixed orthodontic appliance, always develops greater plaque accumulation and deposition of stain on teeth surfaces. (67) Recently, many orthodontic patients ask for procedures of tooth whitening (68). However, tooth whitening should be achieved better at the end of orthodontic treatment after debonding of brackets and bands.(69)

Arboleda-Lopez et al (69) showed that bleaching technique was effective andaltered the teeth shade with or without orthodontic brackets. Salehi et al. (70). compared microleakage scores of different bleaching techniques under orthodontic brackets, they found that higher microleakage values under the brackets of the office bleaching group, than the home bleaching. Also, they observed that microleakage at occlusal margins of the brackets was less than the gingival margins.

CONCLUSIONS

Microleakage is considered as one of the challenging topics in orthodontics. It plays an essential role in debonding of brackets and WSLs during orthodontic treatment. Mostly, it seems that adhesive type, light cure intensity and bonding technique does not have determinative effect on the microleakage value. Laser etching yielded significantly higher microleakage than phosphoric acid etching, in addition ceramic brackets have less microleakage than metal brackets at the bracket-adhesive interface.

REFERENCES

1. Harper WE. The character of adaption of amalgam to the walls of cavities attained by present methods of instrumentation and the use of the best-known alloys, as indicated by the air pressure test. Dent Rev. 1912; 26(1):179 .
2. Pashley DH, Tay FR, Breschi L, Tjäderhane L, Carvalho RM, Carrilho M, et al. State of the art etch and rinse adhesives. Dent Mater. 2011; 27:1 16.
3. Buyuk SK, Cantekin K, Demirbuga S, Ozturk MA. Are the low shrinking composites suitable for orthodontic bracket bonding? Eur J Dent. 2013; 7:284 8.
4. Canbek K, Karbach M, Gottschalk F, Erbe C, Wehrbein H. Evaluation of bovine and human teeth exposed to thermocycling for microleakage under bonded metal brackets. J Orofac Orthop. 2013; 74:102 12.
5. Srivastava K, Tikku T, Khanna R, Sachan K. Risk factors and management of white spot lesions in orthodontics. J Orthod Sci. 2013;2(2):43–9.
6. Ogaard B, Rolla G, Arends J. Orthodontic appliances and enamel demineralization. Am J Orthod Dentofacial Orthop. 1988;94(1):68–73.
7. Tufekci E, Dixon JS, Gunsolley JC, Lindauer SJ. Prevalence of white spot lesions during orthodontic treatment with fixed appliances. Angle Orthod. 2011;81(2):206–10.
8. Arikan S, Arhun N, Arman A, Cehreli SB. Microleakage beneath ceramic and metal brackets photopolymerized with LED or conventional light curing units. Angle Orthod. 2006; 76(6):1035-40.
9. Komori A, Ishikawa H. Evaluation of a resin-reinforced glass ionomer cement for use as an orthodontic bonding agent. Angle Orthod 1997; 67: 189-195.
10. Shankar P, Venkatesan R, Senthil D, Trophimus J, Arthilakshmi CU, Princy P. Microleakage patterns of glass ionomer cement at cement-band and cement-enamel interfaces in primary teeth. Indian J Dent Res 2020; 31: 291-296.
11. Williams PH, Sherriff M, Ireland AJ. An investigation into the use of two polyacid-modified composite resins (compomers) and a resin-modified glass poly(alkenoate) cement used to retain orthodontic bands. Eur J Orthod. 2005; 27: 245-51.
12. Shimazu K, Ogata K, Karibe H. Evaluation of the caries-preventive effect of three orthodontic band cements in terms of fluoride release, retentiveness, and microleakage. Dental Mater J. 2013; 32(3): 376-380.
13. Lopes MB, Consani S, Gonini-Júnior A, Moura SK & McCabe JF. Comparison of microleakage in human and bovine

substrates using confocal microscopy. Bull Tokyo Dent Coll. 2009; 50:111-16.

14. Al- Hamidi MM, Al-Khatib AR. Overview on the Microleakage in Orthodontics. International Medical Journal. 2019;26(2): 139 –41 .
15. Tecco S, Traini T, Caputi S, Festa F, de Luca V, D'Attilio M. Anew one step dental flowable composite for orthodontic use: an in vitro bond strength study. Angle Orthod. 2005;75(4):672-77.
16. Ulker M, Uysal T, Ramoglu SI, Ertas H. Microleakage under orthodontic brackets using high-intensity curing lights. Angle Orthod 2009; 79: 144-9.
17. Miyazaki M, Hinoura K, Onose H, Moore BK. Effect of filler content of light-cured composites on bond strength to bovine dentine. J Dent 1991; 19(5): 301-3.
18. Kidd E. Microleakage: a review. J Dent 1976; 4: 199-206.
19. Youssef M, Youssef F, Souza – Zaroni W, Turbino M, Vieira M. Effect of enamel preparation method on in vitro marginal microleakage of a flowable composite used as a pit and fissure sealant. Int J Paediatr Dent 2006; 16(5): 342-7.
20. Uysal T, Ulker M, Ramoglu SI, Ertas H. Microleakage under metallic and ceramic brackets bonded with orthodontic self-etching primer systems. Angle Orthod. 2008; 78:1089-94 .
21. Hamamci N, Akkurt A, Basaran G. In vitro evaluation of microleakage under orthodontic brackets using two different laser etching, self-etching and acid etching methods. Lasers Med Sci.2010; 25:811-6.
22. Alkis H, Turkkahraman H, Adanir N. Microleakage under orthodontic brackets bonded with different adhesive systems. Eur J Dent 2015; 9:117-21
23. Pakshir H, Ajami S. Effect of Enamel Preparation and Light Curing Methods on Microleakage under Orthodontic Brackets. J Dent (Tehran). 2015; 12(6):436-46.
24. Bishara SE, Gordan VV, VonWald L, Olson ME. Effect of an acidic primer on shear bond strength of orthodontic brackets. Am J Orthod Dentofacial Orthop 1998; 114:243-7.
25. Bishara SE, VonWald L, Laff oon JF, Warren JJ. Effect of using a new cyanoacrylate adhesive on the shear bond strength of orthodontic brackets. Angle Orthod. 2001; 71:466-9 .
26. Attar N, Taner TU, Tülümen E, Korkmaz Y. Shear bond strength of orthodontic brackets bonded using conventional vs one and two step self-etching/adhesive systems. Angle Orthod 2007; 77:518-23.
27. Arhun N, Arman A, Cehreli SB, Arikan S, Karabulut E, Gülsahi K. Microleakage beneath ceramic and metal brackets bonded with a conventional and an antibacterial adhesive system. Angle Orthod. 2006;76:1028-34.
28. Sabzevari B, Ramazazadeh BA, Mozzami SM and Sharifi A. Microleakage under orthodontic metal

brackets bonded with three different bonding techniques with/without thermocycling. J Dent Mater Tech.2013; 2(1):21-8.

29. Atash R, Fneiche A, Cetik S, Bahrami B, Balon-Perin A, Orellana M, et al. In vitro evaluation of microleakage under orthodontic brackets bonded with different adhesive systems. Eur J Dent. 2017; 11:180-5.
30. Bilen HB, Çokakoğlu S. Effects of one-step orthodontic adhesive on microleakage and bracket bond strength: An in vitro comparative study. Int Orthod. 2020;18(2): 366-73.
31. Cohen WJ, Wiltshire WA, Dawes C, Lavelle CL. Long-term in vitro fluoride release and rerelease from orthodontic bonding materials containing fluoride. Am J Orthod Dentofacial Orthop. 2003; 124:571–6.
32. Ramuglu SI, Uysal T, Ulker M and Ertas H. Microleakage under ceramic and metallic brackets bonded with resin-modified glass ionomer. Angle Orthod. 2009; 79:183-43.
33. Forsten L. Fluoride release and uptake by glass-ionomers and related materials and its clinical effect. Biomaterials. 1998; 19:503–8 .
34. Chapra A, White GE. Leakage reduction with a surface-penetratig sealant around stainless-steel orthodontic brackets bonded with a light cured composite resin. J Clin Pediatr Dent. 2003; 27(3):271-6.
35. Cucu M, Drissen CH, Ferreira PD. The influence of orthodontic bracket base and mesh size on bond strength. SADJ. 2002; 57(1):16-20.
36. Silverman E, Cohen M, Gianelly A A, Dietz V S. A universal direct bonding system for both metal and plastic brackets. Am J Orthod 1972. 62: 236–44.
37. Koo B, Chung C, Vanarsdall R. Comparison of accuracy of bracket placement between direct and indirect bonding techniques. Am J of Orthod Dentofacial Orthop. 1999; 116(3): 346–51.
38. Sondhi A. Efficient and effective indirect bonding. Am J of Orthod Dentofacial Orthop. 1999;115: 352–9.
39. Zachrisson BU and Brobakken BO. Clinical. Comparison of direct versus indirect bonding with different bracket types and adhesives. Am J Orthod. 1978;74: 62–78.
40. Öztürk F., Babacan H., Nalçacı R. and Kuştarcı A. Effects of direct and indirect bonding techniques on bond strength and microleakage after thermocycling. Korean J Orthod. 2009; 39(6): 393–401.
41. Ozturk F, Ersoz M, Ozturk SA, Hatunoğlu E & Malkoç S. Micro-CT evaluation of microleakage under orthodontic ceramic brackets bonded with different bonding techniques and adhesives. Eur J Orthod. 2016; 38:163-9 .
42. Yagci A, Uysal T, Ulker M, Ramoglu SI. Microleakage under orthodontic brackets bonded with the custom base indirect

bonding technique. Europ J Orthod. 2010;32: 259–63 .
43. Weir E, Lawlor A, Whelan A, Regan F. The use of nanoparticles in anti-microbial materials and their characterization. Analyst. 2008; 133:835–45.
44. Abderrhmane B, Eddine LS, Redha OM. A Review on Green Synthesis of CuO Nanoparticles using Plant Extract and Evaluation of Antimicrobial Activity. Asian Journal of Research in Chemistry. 2020;13(1):65-70.
45. Farahani AB, Borzabadi E, Lynch E. Nanoparticles in orthodontics, a review of antimicrobial and anti-caries application. Acta Odontologica Scandinavica. 2014;72(6):413-7.
46. Hedayati Z, Farjood A. evaluation of microleakage under orthodontic brackets bonded with nanocomposites. Contemp Clin Dent. 2018; 9(3):361–66.
47. Omidkhoda M, Heravi F, Gharaei, S, Ragrazi A, Hooshmand T. Incorporation of amorphous calcium phosphate (ACP) into glass ionomer cement: influence on microleakage of cemented orthodontic bands. Biomed Res-India. 2017; 28(2):616-9.
48. Heravi F, Bagheri H, Rangrazi A. Evaluation of Microleakage of Orthodontic Bands Cemented with CPP-ACP-Modified Glass Ionomer Cement. Journal of Advanced Oral Research. 2019; 10(2):128–31,
49. Kim J, Kanavakis G, Finkelman MD. & Lee, M. Microleakage under ceramic flash-free orthodontic brackets after thermal cycling. Angle Orthod. 2016; 86:905–8 .
50. Sorel O, EI Alam R, Changneau G. Comparison of bond strength between simple foil mesh and laser-structured base retention brackets. Am J Orthod Dentofacial Orthop. 2002;122(3):260-6.
51. Al-Hamidi MM, Al-Khatib AR. Microleakage Comparison among Three Orthodontic Brackets and Two Orthodontic adhesives. Al-Rafidain Dent J. 2014; 14(2):312- 9.
52. Sagir S, Usumez A, Ademci E and Usumez S. Effect of enamel laser irradiation at different pulse settings on shear bond strength of orthodontic brackets. Angle orthod.2013; 83(6):973-80.
53. Toodehzaeim MH, Rezaie N. Effect of Saliva Contamination on Microleakage Beneath Bonded Brackets: A Comparison Between Two Moisture-Tolerant Bonding Systems. J Dent (Tehran). 2015; 12:747-55
54. Moosavi H, Ahrari F, Mohamadipour H. The effect of different surface treatments of demineralized enamel on microleakage under metal orthodontic brackets. Progress in Orthodontics. 2013;14(2):1-6.
55. Uysal T, Ramoglu SI, Ulker M, Ertas H. Effects of high intensity curing lights on microleakage under orthodontic bands. Am J Orthod Dentofacial Orthop. 2010; 138:201-7.

56. Oberholzer TG, Du Prees IC, Kidd M. Effect of LED curing on the microleakage, shear bond strength and surface hardness of a resin-based composite restoration. Biomaterials. 2005; 26:3981–1986.
57. Davari A, Yassaei S, Karandish M, Zarghami F. In vitro evaluation of microleakage under ceramic and metal brackets bonded with LED and plasma arc curing. J Contemp Dent Pract. 2012;13: 644-9.
58. Bordea IR, Sîrbu A, Lucaciu O, Ilea A, Câmpian RS, Todea DA, Alexescu TG, Aluaș M, Budin C, Pop AS. Microleakage - The Main Culprit in Bracket Bond Failure? J Mind Med Sci. 2019; 6(1): 86-94 .
59. Wahab FK, Shaini FG and Morgano SM. The effect of thermocycling on microleakage of several commercially available composite class V restorations in vitro. J Prosthet Dent. 2003;90(2): 168-70.
60. Daub J, Berzins DW, Linn BJ and Bradley TG. Bond strength of direct and indirect bonded brackets after thermocycling. Angle Orthod. 2006;76(2):295-300.
61. Sabzevari, B, Ramazazadeh, BA, Mozzami SM, Sharifi A. Microleakage under orthodontic metal brackets bonded with three different bonding techniques with/without thermocycling. J Dent Mater Tech. 2013;2(1)21-8.
62. Kustarci A, Sokucu O. Effect of chlorhexidine gluconate, Clearfil Protect Bond, and KTP laser on microleakage under metal orthodontic brackets with thermocycling. Photomed Laser Surg. 2010; 28:57-62.
63. Dinçer B, Hazar S, Sen BH. Scanning electron microscope study of the effects of soft drinks on etched and sealed enamel. Am J Orthod Dentofacial Orthop. 2002; 122(4):135–41 .
64. Navarro R, Vicente A, Ortiz AJ & Bravo LA. The effects of two soft drinks on bond strength, bracket microleakage, and adhesive remnant on intact and sealed enamel. Eur J Orthod. 2011; 33:60-5.
65. Toodehzaeim MH, Rezaie N. Effect of Saliva Contamination on Microleakage Beneath Bonded Brackets: A Comparison Between Two Moisture-Tolerant Bonding Systems. J Dent (Tehran). 2015; 12:747-55.
66. Çörekçi B, Irgın C, Malkoç S & Öztürk B. Effects of staining solutions on the discoloration of orthodontic adhesives: an in-vitro study. Am J Orthod Dentofacial Orthop. 2010; 138:741-6.
67. Trakyalı G, Özdemir FI, Arun T. Enamel colour changes at debonding and after finishing procedures using five different adhesives. Eur J Orthod. 2009; 31:397-401.
68. Slack ME, Swift EJ, Rossouw PE & Phillips, C. Tooth whitening in the orthodontic practice: A survey of orthodontists. Am J Orthod Dentofacial Orthop. 2013;143: S64-S71
69. Arboleda-Lopez C, Manasse RJ, Viana G, Bedran-Russo AB & Evans, CA

(Tooth Whitening during Orthodontic Treatment: A Six-Month In vitro Assessment of Effectiveness and Stability. Int J Dent Oral Health. 2015; 1:1-4.

70. Salehi P, Malekpour B, Roshan A, Hamedani Sh. Effect of Different Bleaching Techniques on Microleakage under orthodontic Brackets: In Vitro Study. J Dent Biomate. 2018;5(1):503-5 .