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The Accuracy of Bracket Placement using L-Shaped Printed Guide Method and the Digital Indirect Tray Method..

Ahmed Mohamed Kilany[1], Mostafa Magdi Abdelmonem AbdelAllah[2], Mostafa Mohamed Mahmoud Dawaba[3], Hussein Shokry Hassan Ahmed[4], Esmail Kamal Hewy Raslan[5], Ahmed Mahmoud Ahmed Ali[6], Mahmoud Mohamed Salah Eldin[7]

[1]Lecturer, Orthodontic Department, Faculty of Dental Medicine, Al-Azhar University (Assiut Branch), Assiut, Egypt. Email ID : kilany.forever@gmail.com

[2]Associate professor, Orthodontic Department, Faculty of Dental Medicine, Al-Azhar University (Assiut Branch), Assiut, Egypt. Email ID : MostafaAbdelAllah1251.el@azhar.edu.eg

[3]Associate professor, Orthodontic Department, Faculty of Dental Medicine, Al-Azhar University (Assiut Branch), Assiut, Egypt. Mustafadawaba1425.el@azhar.edu.eg

[4]Associate professor, Orthodontic Department, Faculty of Dental Medicine, Al-Azhar University (Assiut Branch), Assiut, Egypt. hu_ma_82@yahoo.com

[5]Lecturer, Orthodontic Department, Faculty of Dental Medicine, Al-Azhar University (Assiut Branch), Assiut, Egypt. Esmailhewy1459.el.azhar.edu.eg

[6]Lecturer, Orthodontic Department, Faculty of Dental Medicine, Al-Azhar University (Assiut Branch), Assiut, Egypt. AhmedAli29.el@azhar.edu.eg

[7]Lecturer, Orthodontic Department, Faculty of Dental Medicine, Al-Azhar University (Assiut Branch), Assiut, Egypt. Mahmoud.Salah.ortho@gmail.com

ABSTRACT

Objectives: to compare the accuracy of bracket placement using L shaped printed guide and digital indirect tray using virtual models.

Methods: This randomized clinical trial included 20 patients selected from the orthodontic outpatient clinics at Al-Azhar University, Assiut. Patients with full permanent dentition with complete clinical crown height and no previous orthodontic treatment were randomly assigned to receive bracket bonding by L shaped guide and digital indirect tray to obtain virtual models prebonding and post bonding to detect the deviation (linear and angular) of brackets for two methods. The variables were measured for each patient in each group for incisors, canines, and premolars.

Results: The guided group showed less deviation than indirect group with significant difference between them present at all linear variables for all teeth except for premolar at mesiodistal deviation while angular deviation showed only differences in some brackets for certain teeth.

Conclusion: Guided method provided more precise technique for bracket bonding at accurate position at different planes when compared to indirect tray method.

Keywords: Orthodontics brackets, Guide, indirect bond, soft tray, and virtual models...

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1. INTRODUCTION

At present, the preadjusted bracket appliance is the most employed orthodontic treatment modality. This technique relies on precise bracket placement to achieve ideal occlusion, appropriate faciolingual torque, and correct mesiodistal tip using a straight wire(1, 2).

Direct bonding of orthodontic brackets represents the most commonly used clinical procedure in orthodontics.(3-5) This method involves a single-step placement of brackets directly onto the teeth. Typically, brackets are positioned at the center of the clinical crown, aligning the mesiodistal borders of the bracket base with the crown's long axis and positioning the slot center at the crown midpoint. In some straight-wire techniques, bracket placement varies according to the tooth type, with adjustments in the vertical distance from the incisal edge while preserving alignment with the crown's long axis(6)..

Precision in bracket placement is a critical factor in achieving successful orthodontic results. Proper bracket positioning enhances biomechanical efficiency and ensures more predictable treatment outcomes[7-10].

Conversely, inaccurate bracket positioning in modern straight-wire systems using preadjusted appliances increases treatment time due to the need for repeated wire adjustments or rebonding procedures[8, 11-14].

Computer-aided design and manufacturing (CAD/CAM) technology facilitates the creation of customized orthodontic devices through 3D printing and advanced digital image manipulation. This technique ensures precise and efficient aligner fabrication. Digital processes such as virtual bracket debonding, indirect bonding tray design, and customized appliance fabrication are integral to retainer production. The workflow includes digital intraoral scanning, software-based image modification, and 3D printing of the final appliances[15, 16].

Advances in digital orthodontics have significantly enhanced clinical outcomes by reducing chairside time, improving bonding accuracy, and accelerating treatment progress. Establishing a balanced occlusion after treatment requires precise biomechanical control, accurate bracket placement, careful planning, and reliable diagnostic tools. Proper bracket bonding plays a vital role in distributing occlusal forces evenly during mastication and in achieving optimal esthetics. Furthermore, root parallelism, aligned dentition, and leveled marginal ridges are fundamental to maintaining functional stability[17].

A comprehensive and systematic diagnosis is the cornerstone of optimal bracket placement. Both conventional straight-wire appliances and modern computer-assisted orthodontic systems utilizing customized brackets and robotically bent wires rely on the accurate transfer of planned bracket positions. As a result, a variety of bracket placement tools and transfer trays have been developed to ensure precise positioning on the teeth[18-23].

Recent advancements in digital modeling, intraoral scanning, and 3D printing have expanded the possibilities for accurate bracket placement. To address the limitations of traditional bonding methods, several digitally guided tray and guide fabrication techniques have been proposed, with the orthodontist retaining full control over the design and manufacturing stages[24].

In present study, we compared the accuracy of brackets bonding between L shaped guided method and indirect bonding tray. The null hypotheses of the study were that there is no difference between two methods of brackets bonding.

2. MATERIALS AND METHODS

Study Design: Randomized clinical trial.

Ethical Consideration

The study received ethical approval from the Faculty of Dental Medicine's Institutional Review Board (AUAREC20220007-3).

Participants

Participants were selected from Al-Azhar University's Orthodontic Clinic, faculty of dental medicine (Assiut branch). Eligibility was based on strict inclusion and exclusion criteria.

Inclusion Criteria:

1.Presence of a full complement of maxillary dentition from first molar to first molar.

2.Good oral hygiene.

3.Healthy periodontium.

4. Spaced upper arch or crowding no more than 4 mm.

Exclusion Criteria:

1.Presence of primary teeth or crowding more than 4mm.

2.Missed permanent tooth from first molar to first molar.

3.Malformed teeth or impacted teeth.

4.Enamel fluorosis.

5.Partially erupted tooth or restored tooth.

6.Tooth with major rotation impeding proper bracket positioning.

Sample size calculation:

Based on previous study [25] and Using G power statistical power Analysis program (version 3.1.9.4) for sample size determination, A total sample size (n=16) was sufficient in the study to detect a large effect size (f)= 0.4580 between two group, with an actual power (1-β error) of 0.85 (85%) and a significance level (α error) 0.05 (5%) for two-tailed hypothesis test. The sample size was increased by 20% to compensate for possible patient drop-out, giving a total of n=10 for each group

Grouping and randomization:

The patients were randomly divided into two groups.

Group (I): L shape guide bracket placement group.

Group (II): Indirect bracket placement group using bonding tray.

Intervention:

For each patient included in the present study, digital impressions of the dentition were obtained using Maestro 3D software. The bracket placement function was then activated, and three reference points were marked by the operator on the incisal edge of the incisor and the buccal cusps of the right and left first molars to establish the occlusal plane. Based on the clinical crown morphology, the software automatically identified and locked the facial axis (FA) points and centers of rotation for each tooth. Subsequently, 0.022-inch preadjusted edgewise brackets (Discovery Smart brackets, Dentaurum, Germany) with Roth prescriptions were selected from the software library. The bracket positions were verified and saved as STL files, which were then transferred to the Appliance Designer module of the Real Guide software for bonding guide fabrication. Once the virtual bracket placement has been confirmed the virtual model for the upper arch with the bracket on it has been saved as reference model (M1) Figure (1)

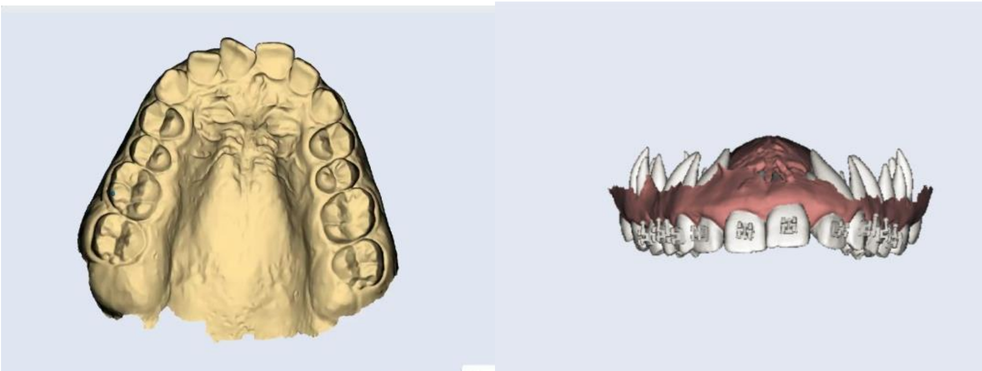

Figure (1): showed scanned dentition on the software and virtual model (M1)

For group (I): A new digital workflow was implemented to design the direct guided bonding device, which is composed of an occlusal shell, an L-shaped guide, and a connecting bar connecting the two components. Figure (2)

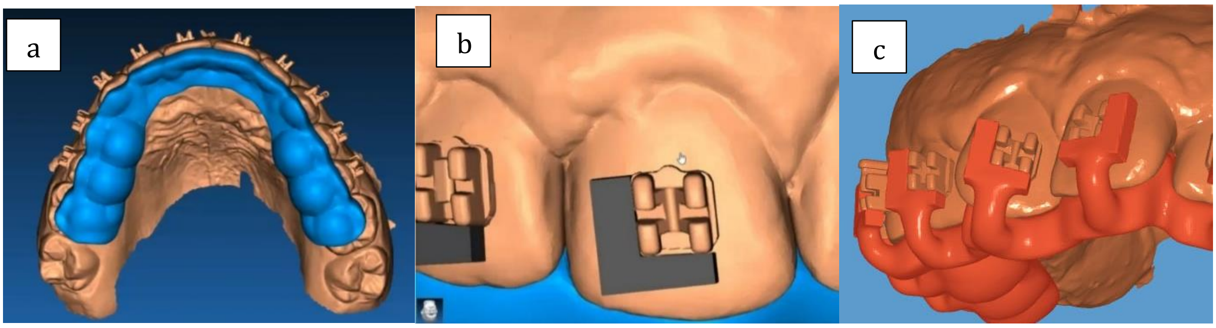

Figure (2): showed components of the guided. (a) occlusal shell, (b) L-shaped guide, (c) connecting bar

After finalizing the guide design, the device was exported in STL format for 3D printing. Fabrication of the guided bonding device was carried out using a NextDent 5100 3D printer and Ortho Clear resin. Figure (3)

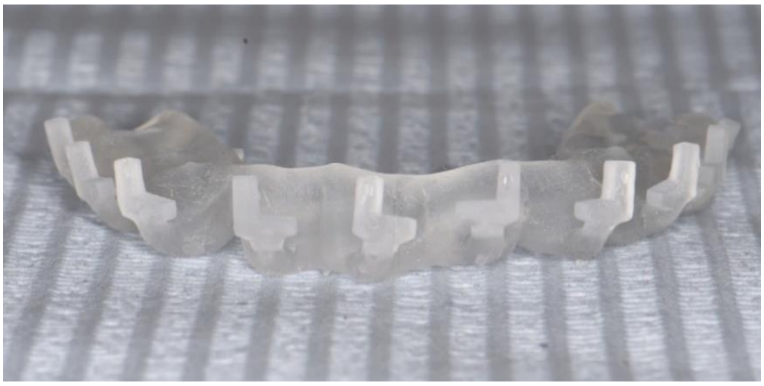

Figure (3): showed 3D printed guided bonding device.

Bonding was carried out using the guided bonding appliance, and patients were asked to bite on cotton rolls to confirm accurate adaptation of the device to the dentition. After completing standard etching and adhesive application steps, a thin layer of orthodontic composite (Green Gloo, Ormco) was applied to the base of each 0.022-inch preadjusted edgewise bracket. Figure (4)

Figure (4): Showed bracket placement according to device and brackets adaptation to the L-shape guide horizontally and vertically.

It was important to adjust the vertical and horizontal position of the brackets so that the brackets would perfectly fit into the customized L-shaped guide. After curing all brackets, it was easy to remove the guided bonding device through its path of insertion by Using a dental probe.

For group (II): The virtual bracket transfer tray was designed on (M1). A tray has thickness of 0.75 mm and covers the incisal/occlusal surfaces as well as part of palatal surface of each tooth. Facially, the tray overlapped the brackets gingival to the bracket slot. Figure (5)

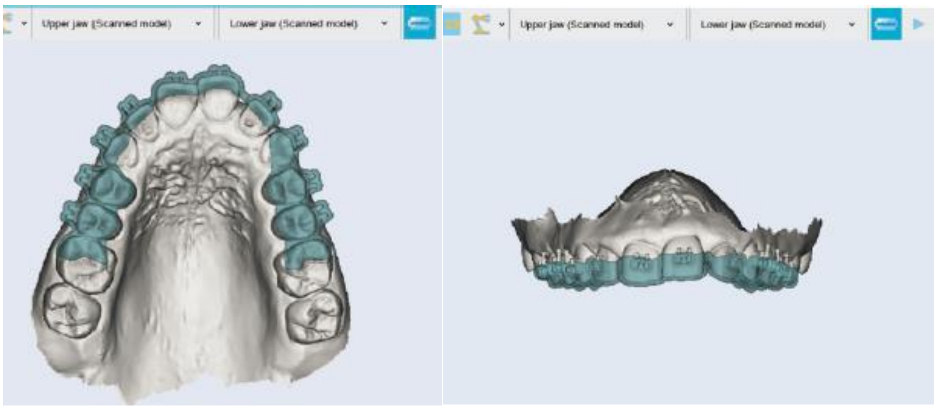

Figure (5): Showed Transfer tray designing occlusal and frontal view.

The transfer tray with support structures was printed using LD-006 3D printer (Creality, Shenzhen, China) and biocompatible flexible resin for group II. Support structures were removed from the 3D-printed tray then sectioned in the midline into two halves.

Brackets were carefully positioned inside respective molds in the transfer tray, A thin layer of Grengloo adhesive (ORMCO, California, USA) was applied to the bracket's base and homogenously dispersed with a micro brush and a thin layer of Ortho solo™ (ORMCO, California, USA). Figure (6)

Figure (6): showed Transfer tray loaded with brackets.

Transfer tray loaded with brackets was then inserted and completely seated over the teeth after preparation of the upper arch with etching and bond, one quadrant at a time, and gently fixated manually during curing with I-led curing light (Woodpecker, Guangxi, China). Figure (7)

Figure (7): showed transfer tray insertion, curing and removing.

Intra oral scanning of the bonded brackets was made for groups of the study to provide a post-transfer STL file that was saved for subsequent superimposition.

Pre-bonding model (M1) and post-bonding virtual model (M2) were prepared and superimposed using GOM inspect software. The X, Y, and Z-axes were manually added to each bracket creating a local coordinate system in pre and post bonding records in both groups.

The X-axis represented the mesiodistal dimension, the Y-axis represented the buccolingual dimension, while the Z-axis represented the occluso-gingival dimension. The deviations between pre and post bonding virtual models in both groups were quantified in reference to the local coordinate systems in two linear values (millimeter) and two angular values (degrees) along the axes X, Y and Z.

Measurements:

The linear deviations of brackets position, measured in millimeters, were as follows:

Mesio-distal

Occluso-gingival

The angular deviations of brackets position, measured in degrees, were as follows:

Tip

Rotation

Statistical Analysis

Data of different variables of samples were collected for the prebonding virtual cast and post bonding virtual cast and for each group to make comparison between two methods to evaluate deviation at all planes. Data were analyzed using IBM SPSS Statistics version 22.0 (IBM, Armonk, NY). Data normality was checked via distributional diagrams and Shapiro-Wilk test. For the outcomes, which were normally distributed, descriptive statistics were given mean ± SD. Independent Samples Test was used to compare between two different groups.

Results:

Deviation Analysis showed in table (1) and table (2).

There were less deviations recorded for guided group as compared with indirect method either in the linear deviation or the angular one except for.

The mesiodistal and occlusogingival deviation showed significant differences between guided method and indirect method with all teeth except premolars at mesiodistal deviation there were non- significant difference.

As regard to angular deviation, there were non- significant difference between two groups except for canine at tip deviation and incisors at rotation deviation where there were significant differences with less deviation at indirect method group.

Table (1): Show comparison between two groups for different linear deviation:

Deviation	Mesio-distal (mm) Deviation			Occluso-gingival (mm) Deviation		
Groups	G (I) Mean±SD	G (II) Mean±SD	p value	G (I) Mean±SD	G (II) Mean±SD	p value
Incisors	(.167±.064)	(.310±.014)	.000*	(.220±.144)	(.342±.032)	.018*
Canine	(.191±.133)	(.312±0.033)	.012*	(.117±.064)	(.356±.021)	.000*
Premolars	(.199±.188)	(.316±.028)	.069NS	(.169±.067)	(.364±.022)	.000*

G; group, SD; standard deviation, * significant difference, NS; non-significant difference

Table (2): Show comparison between two groups for different angular deviation:

Deviation	Tip (°) Deviation			Rotation (°) Deviation		
Groups	G (I) Mean±SD	G (II) Mean±SD	p value	G (I) Mean±SD	G (II) Mean±SD	p value
Incisors	(1.97±.645)	(1.55±.103)	.061NS	(1.98±.478)	(1.22±.014)	.000*
Canine	(1.01±.486)	(1.62±.048)	.001*	(1.31±.424)	(1.22±.041)	.513NS
Premolars	(1.46±.525)	(1.65±.070)	.268NS	(1.57±.576)	(1.23±.062)	.079NS

G; group, SD; standard deviation, * significant difference, NS; non-significant difference

In guided group, the lowest deviation in linear measurements was in mesiodistal deviation (canines) with a mean of .117 mm, while the highest deviation was reported in occlusogingival deviation (incisors) with a mean of .220 mm. In angular measurements, the lowest deviation was in tip deviation (canines) with a mean of 1.01°, while the highest deviation was reported in rotation deviation (incisors) with a mean of 1.98°.

In indirect group, the lowest deviation in linear measurements was in the mesiodistal deviation (incisors) with a mean of .310 mm, while the highest deviation was reported in occlusogingival deviation (premolars) with a mean of .364 mm. In angular measurements, the lowest deviation was in rotation deviation (incisors) with a mean of 1.22°, while the highest deviation was reported in tip deviation (premolars) with a mean of 1.65°.

3. DISCUSSION:

The most popular orthodontic therapy technique nowadays is the preadjusted bracket system. The fundamental idea behind the preadjusted technique is that when the brackets are positioned correctly, the teeth can be placed into an occlusal contact with excellent faciolingual inclination (torque) and mesiodistal inclinations (tips) using a straight wire[1, 2].

To avoid the adverse effect caused by incorrect bracket positioning with pre-adjusted appliances which leads to increased treatment time, due to the need for either several wire bending steps or bracket rebonding, accurate bracket placement must be performed[8, 11-14].

To accurately transfer the planned bracket placement to patients' teeth, several types of transfer trays have been created utilizing computer technologies such CBCT, CAD/CAM, and 3D printing[26-29]. However, the effectiveness of such devices may be questioned in relation to their precision, reliability, degree of technological know-how, and fabrication cost [25, 30].

The current study therefore established simple digital technology for precise and reliably placing orthodontic brackets directly, comparing its accuracy to that of indirect bonding technique.

Virtual bonding was carried out in both groups using the Ortho Analyzer module (Maestro 3D software). An easy workflow, from teeth segmentation to bracket validation step, was used to ensure that brackets were placed correctly and accurately with simulation of the orthodontic teeth movement. The Auto segmentation property allowed for automatic virtual positioning of the brackets with operator ability to adjust the positional errors before validation of the virtual bonding. Additionally, this software has a large library of bracket systems[31, 32].

Virtual designing and direct printing of the transfer trays was used in this study to eliminate the need for transfer model printing, reduce the consumed material, save time, and enable that the entire process is virtual until the actual printing of the bracket transfer tray.

To precisely locate the brackets, the guided bonding device was created using the Appliance Designer panel of Real guide software (real guide v5.3, 3diemme- Italy) Utilizing intra-operative position control during bracket placement, the guided bonding device capitalized on the direct bonding technique. Additionally, the guide was 3D printed directly rather than using models and then building the tray, which saved a lot of time and money.

The design of the guide was L shape which incircle the bracket form two sides only (distal and occlusal), so we can easily remove any excess composite flash to avoid plaque buildup and maintain the integrity of the enamel surface. And there was adequate distance between the guide and labial surface of the tooth that ensure complete curing of the adhesive was achieved[25].

The linear outcomes of group II were higher than those found by Faus-Matoses et al.[32] in which the mean mesio-distal deviation was 0.065 ± 0.081 mm, and the mean vertical deviation was 0.094 ± 0.147 mm.; and Park et al.[33] when evaluated the accuracy of a CAD/CAM-fabricated one-piece bracket jig system, in which the average linear measurements ranged from 0.029 to 0.101 mm.; and Kim et al.[34] which varied between 0.09 ± 0.01 mm for mesiodistal error and 0.19 ± 0.2 mm for occlusogingival error using transfer jigs fabricated by CAD/CAM; and Pottier et al.[35] when they compared 3D printed tray with silicon transfer tray, the mean transfer errors for 3D printed tray in MD and OG directions were 0.198 ± 0.110 mm. and 0.197 ± 0.233 mm. respectively.

Both groups' actual bracket positions following bonding were compared to the planned bracket positions determined by the software. The results of the current study showed that, despite the presence of a positional deviation in both groups, all the resultant deviation values in indirect bonding group and the digitally assisted direct bonding group fell within the clinically acceptable range of deviations (0.5 mm for the linear and 2 for the angular), as established by Grunheid et al[22]. so the digitally aided approach can be used confidently in daily clinical practice by orthodontists despite of the resultant deviations.

In agreement with Xue et al.,[25] the current study's findings demonstrated that the brackets in group I were precisely positioned by the guided bonding device in both the occlusal-gingival and mesio-distal planes. During the design process, the L-shape part was customized around the bracket boundaries using the software's model subtraction capability, which assured a perfect fit of the brackets into the resulting indentation of the L-shape part. This ensured positional accuracy both horizontally and vertically. Additionally, the 0.01 mm offset that was included in the shell design reduced the brackets' occluso-gingival deviations by perfectly fitting the shell over the teeth. While the found bucco-lingual deviations were due to difference between the amount of adhesive paste used on each bracket base and that was previously simulated on the software.

The digitally assisted group's linear readings (group I) were opposite to Kim et al.(34) findings, who discovered a maximum vertical positional error of 0.71 mm, which is higher than the range that is considered clinically acceptable. A free space between the tray and the teeth resulted from the cusp tip recontouring's inaccuracy, which caused the vertical error.

This incisal/occlusal bias of group II corroborates the outcomes of Niu et al.(36) and Castilla et al.(37) and explained their results by inadequate tray seating due to a minor lack of alignment between the bracket and the hard transfer tray, and by deficient vertical pressure on the tray during the light-curing procedure.

There is a limitation of the current study is the learning curve needed to use virtual bonding, intraoral scanners, and software to create customized appliances. Soon, all orthodontic accessories will probably be digital, though, as software systems become more affordable and simpler to use in routine practice.

4. CONCLUSION:

Within the limitation of the present study, we concluded the following:

There were differences between two methods of bonding with more accuracy for L shape guided groups.

Guided method provided more precise technique for bracket bonding at accurate position at different planes when compared to indirect methods.

The guided direct bonding method employed in this study was precise, reliable, and fell within the range of clinically acceptable errors without immediate bonding failure.

The customized L shape guide used in this study reduced the number of positional errors that could occur during bracket placement using the traditional technique in both linear and angular directions

REFERENCES

1. Balut N, Klapper L, Sandrik J, Bowman D. Variations in bracket placement in the preadjusted orthodontic appliance. American journal of orthodontics and dentofacial orthopedics. 1992;102(1):62-7.
2. Weber 2nd DJ, Koroluk LD, Phillips C, Nguyen T, Proffit WR. Clinical effectiveness and efficiency of customized vs. conventional preadjusted bracket systems. J Clin Orthod. 2013;47(4):261-6.
3. Carstensen W. Clinical results after direct bonding of brackets using shorter etching times. American Journal of Orthodontics. 1986;89(1):70-2.
4. Li Y, Mei L, Wei J, Yan X, Zhang X, Zheng W, et al. Effectiveness, efficiency and adverse effects of using direct or indirect bonding technique in orthodontic patients: a systematic review and meta-analysis. BMC oral health. 2019;19:1-11.
5. Zachrisson BU. A posttreatment evaluation of direct bonding in orthodontics. American journal of orthodontics. 1977;71(2):173-89.
6. Armstrong D, Shen G, Petocz P, Darendeliler MA. A comparison of accuracy in bracket positioning between two techniques—localizing the centre of the clinical crown and measuring the distance from the incisal edge. The European Journal of Orthodontics. 2007;29(5):430-6.
7. Kalra RK, Mittal S, GanDiKota C, Sehgal V, Gupta R, Bali Z. Comparison of Accuracy of Bracket Placement by Direct and Indirect Bonding Techniques using Digital Processing-An In-Vitro Study. Journal of Clinical & Diagnostic Research. 2018;12(9).
8. McLaughlin R. Bracket placement with the preadjusted appliance. J Clin Orthod. 1995;29:302-11.
9. Andrews LF. The six keys to normal occlusion. Am J orthod. 1972;62(3):296-309.
10. Pisani L, Bonaccorso L, Fastuca R, Spena R, Lombardo L, Caprioglio A. Systematic review for orthodontic and orthopedic treatments for anterior open bite in the mixed dentition. Progress in orthodontics. 2016;17:1-14.
11. Carlson SK, Johnson E. Bracket positioning and resets: five steps to align crowns and roots consistently. American Journal of Orthodontics and Dentofacial Orthopedics. 2001;119(1):76-80.
12. Miethke RR, Melsen B. Effect of variation in tooth morphology and bracket position on first and third order correction with preadjusted appliances. American Journal of Orthodontics and Dentofacial Orthopedics. 1999;116(3):329-35.

13. Arreghini A, Lombardo L, Mollica F, Siciliani G. Torque expression capacity of 0.018 and 0.022 bracket slots by changing archwire material and cross section. Progress in orthodontics. 2014;15:1-18.
14. Lombardo L, Toni G, Stefanoni F, Mollica F, Guarneri MP, Siciliani G. The effect of temperature on the mechanical behavior of nickel-titanium orthodontic initial archwires. The Angle Orthodontist. 2013;83(2):298-305.
15. Tack P, Victor J, Gemmel P, Annemans L. 3D-printing techniques in a medical setting: a systematic literature review. Biomedical engineering online. 2016;15:1-21.
16. Dawood A, Marti BM, Sauret-Jackson V, Darwood A. 3D printing in dentistry. British dental journal. 2015;219(11):521-9.
17. Soares Ueno EP, de Carvalho TCAdSG, Kanashiro LK, Ursi W, Chilvarquer I, Neto JR, et al. Evaluation of the accuracy of digital indirect bonding vs. conventional systems: a randomized clinical trial. The Angle Orthodontist. 2025;95(1):3-11.
18. Silverman E, Cohen M, Gianelly AA, Dietz VS. A universal direct bonding system for both metal and plastic brackets. American journal of orthodontics. 1972;62(3):236-44.
19. Koga M, Watanabe K, Koga T, editors. Quick Indirect Bonding System (Quick IDBS): an indirect bonding technique using a double-silicone bracket transfer tray. Seminars in Orthodontics; 2007: Elsevier.
20. Thomas RG. Indirect bonding: simplicity in action. Journal of clinical orthodontics: JCO. 1979;13(2):93-106.
21. Ciuffolo F, Epifania E, Duranti G, De Luca V, Raviglia D, Rezza S, et al. Rapid prototyping: a new method of preparing trays for indirect bonding. American Journal of Orthodontics and Dentofacial Orthopedics. 2006;129(1):75-7.
22. Grünheid T, Lee MS, Larson BE. Transfer accuracy of vinyl polysiloxane trays for indirect bonding. The Angle Orthodontist. 2016;86(3):468-74.
23. Schubert K, Halbich T, Jost-Brinkmann P-G, Müller-Hartwich R. Precision of indirect bonding of lingual brackets using the Quick Modul System (QMS)®. Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopadie. 2013;74(1).
24. Christensen LR, Cope JB, editors. Digital technology for indirect bonding. Seminars in Orthodontics; 2018: Elsevier.
25. Xue C, Xu H, Guo Y, Xu L, Dhami Y, Wang H, et al. Accurate bracket placement using a computer-aided design and computer-aided manufacturing–guided bonding device: an in vivo study. American Journal of Orthodontics and Dentofacial Orthopedics. 2020;157(2):269-77.
26. Balut N, Thakkar DP, Gonzalez E, Eluani R, Silva LD. Digital orthodontic indirect bonding systems: A new wave. APOS Trends Orthod. 2020;10(3):195-200.
27. Garino F, Garino GB. Computer-aided interactive indirect bonding. Prog Orthod. 2005;6(2):214-23.
28. Israel M, Kusnoto B, Evans CA, BeGole E. A comparison of traditional and computer-aided bracket placement methods. The Angle Orthodontist. 2011;81(5):828-35.
29. Son K-H, Park J-W, Lee D-K, Kim K-D, Baek S-H. New virtual orthodontic treatment system for indirect bonding using the stereolithographic technique. Korean Journal of Orthodontics. 2011;41(2):138-46.
30. CUNHA TdMAd, BARBOSA IdS, Palma KK. Orthodontic digital workflow: Devices and clinical applications. Dental Press Journal of Orthodontics. 2021;26(06):e21spe6.
31. Nucera R, Militi A, Caputo A, Bellocchio AM, Minervini G, Cervino G, et al. Indirect orthodontic bonding using an original 3D method compared with conventional technique: A narrative review. The Saudi Dental Journal. 2024;36(1):72-6.
32. Al-Ubaydi AS, Al-Groosh D. Do the Various Indirect Bonding Techniques Provide the Same Accuracy for Orthodontic Bracket Placement?(Randomized Clinical Trial). International Journal of Dentistry. 2024;2024(1):5455197.
33. Park J-H, Choi J-Y, Kim S-H, Kim S-J, Lee K-J, Nelson G. Three-dimensional evaluation of the transfer accuracy of a bracket jig fabricated using computer-aided design and manufacturing to the anterior dentition: an in vitro study. Korean Journal of Orthodontics. 2021;51(6):375-86.
34. Kim J, Chun Y-S, Kim M. Accuracy of bracket positions with a CAD/CAM indirect bonding system in posterior teeth with different cusp heights. American Journal of Orthodontics and Dentofacial Orthopedics. 2018;153(2):298-307.
35. Pottier T, Brient A, Turpin YL, Chauvel B, Meuric V, Sorel O, et al. Accuracy evaluation of bracket repositioning by indirect bonding: hard acrylic CAD/CAM versus soft one-layer silicone trays, an in vitro study. Clinical oral investigations. 2020;24(11):3889-97.
36. Niu Y, Zeng Y, Zhang Z, Xu W, Xiao L. Comparison of the transfer accuracy of two digital indirect bonding trays for labial bracket bonding. The Angle Orthodontist. 2021;91(1):67-73.

37. Castilla AE, Crowe JJ, Moses JR, Wang M, Ferracane JL, Covell Jr DA. Measurement and comparison of bracket transfer accuracy of five indirect bonding techniques. The Angle Orthodontist. 2014;84(4):607-14..