Direct and indirect bonding techniques in orthodontics: a systematic review

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Abstract. – OBJECTIVE: Some of the most significant aspects in orthodontics for achieving favorable treatment outcomes include correct bracket positioning and a shorter period to accomplish bracket bonding. Two different brackets bonding techniques – direct and indirect bonding – are described in the literature. The aim of this review is to evaluate the differences, advantages, and disadvantages of the two techniques.

MATERIALS AND METHODS: A literature search was conducted on PubMed, Scopus, and Web of Science databases in a period from January 2013 to April 2023 with English language restriction using the following Boolean keywords: "orthodontic bracket* AND (bonding OR placement)".

RESULTS: A total of 3,820 articles were identified by the electronic search, and after duplicate removal, screening, and eligibility, a total of 11 papers were included for the qualitative analysis.

CONCLUSIONS: Indirect bonding is more predictable and precise than direct bonding. Indirect bonding has a greater impact on minimizing bracket placement errors than direct bonding, but it still takes longer to complete than the traditional procedure. However, further studies on the differences between direct and indirect bonding, as well as digital bonding, are needed.

Key Words:
Orthodontics, Bonding technique, brackets, Direct technique, Indirect technique, Tooth bonding.

Abbreviations

APC: adhesive pre-coated brackets; ARI: adhesive remanence index; BO: beauty ortho bond; BRK: bracket; BRKs: brackets; CAD/CAM: Computer-Aided Design and Computer-Aided Manufacturing; CBCT: Cone Beam Computed Tomography; CCR: chemically cured resins; DBB: direct bracket bonding; HCR: heat cured resins; IBB: indirect bracket bonding; LCR: light-cured resins; NC: non coated brackets; QLF: quantitative light-induced fluorescence; SBS: shear bond strength; VBP: virtual bracket placement; XT: Transbond; WSLs: white spot lesions.

Introduction

Since the straight wire technique was introduced in orthodontics, an increased need for accurate bracket (BRK) placement on the buccal surface of teeth has been felt following the facial axis of the clinical crown (FACC) (Figures 1 and 2). This is mandatory to avoid unwanted movements such as deviation in rotation, tipping, in/out, extrusion/intrusion, and torque[1,2].

Currently, in orthodontics, there are two techniques for BRK placement. Direct bracket bonding (DBB) is the most traditional and used, which consists of placing the braces individually on the tooth surface[3,4]. The latest and most developed is indirect bracket bonding (IBB), which consists of creating a plaster cast of the patient's dental arch, identifying on this the ideal position of the braces, placing them in removable trays, and positioning them in the oral cavity during a single session[5,6]. As a 2020 literature review by Nawrocka and Lukomska-Szymanska[7] highlights, the development of IBB is a consequence of the development of the adhesive system[7].

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More specifically, IBB was introduced in the 1970s in response to the clinical need to improve the accuracy of orthodontic BRK positioning[2,8,9] and to counteract adverse effects such as a bad oral hygiene status and a high bond failure rate. Moreover, this technique made it possible for orthodontists to reduce their chairside time[10]. More and more clinicians are now looking at this technique with interest, since IBB is a precise and time-saving method of BRK placement, growing in popularity in recent years[7,11].

As mentioned above, the development of adhesion in dentistry and the use of adhesion in orthodontics made possible many relevant changes: the first and most important is probably the passage from bands on the teeth for fixed therapy to braces pasted on the tooth enamel for fixed appliances[12-16].

Tracing back the history of orthodontics, it is possible to recall that adhesion was introduced in orthodontics in the 1960s, but initially, the adhesives showed some limitations[17,18]. In particular, the first adhesives used were epoxy-based: a pioneer in the field was George Newman[17], who in 1965 reported the advantages of this experimental procedure. Nevertheless, these adhesives required a prolonged curing time, and the final hard-ness was achieved after four days: therefore, putting into the brackets the archwire system was impossi-ble[19,20].

Afterward, in 1972 Silverman et al[19] first designed a system to properly position the plastic or metal brackets in a limited amount of time: they were secured with a drop of cement on a cast model, then the orthodontist transferred them to the mouth using a concave tray; after the removal of the tray from the oral cavity, the brackets remain fixed on the teeth surface[21,22] (Figure 3).

Later on, in 1979 Thomas[23] developed a method to attach the BRKs to model casts prepared with chemically cured composite[24]. More specifically, this technique entailed the realization of a proper bonding base for each tooth: this base was used to bind the tooth surface and the BRK by a chemical reaction during the trans-fer into the mouth. Unfortunately, this procedure was inefficient since it was observed that the shear bond strength (SBS) was insufficient[25,26]. Other clinical trials[27] were also conducted in the early 1980s with heat-cured resins (HCR), but this type of adhesion was not good for bonding BRKs. However, after the technique was perfected, it began to yield much more promising results. For instance, in a 1988 study, Hocevar and Vincent[28] reported that IBB could grant a similar bond strength to the BRKs and an easier debonding be-cause less resin was left on the teeth. The following year, a 1989 study by Milne et al[29] pointed out as ad-vantages of the indirect method the shorter application time, the ease of cleaning up excess material, and the precision with which even the least experienced operator could manage to place the brackets using this technique.

In the following years, due to the accurate SBS tests *in vitro* conducted, comparing BRKs bonding systems became possible, and the IBB procedure went towards sound standardization[30]. In parti-

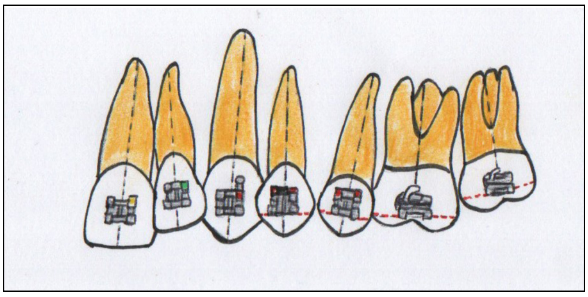

Figure 1. Upper arch; facial axis of the clinical crown (FACC), direct bracket bonding (DBB).

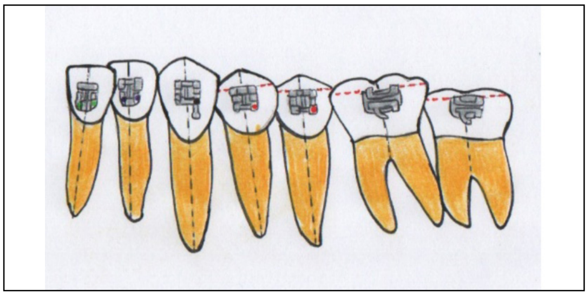

Figure 2. Lower arch; facial axis of the clinical crown (FACC), direct bracket bonding (DBB).

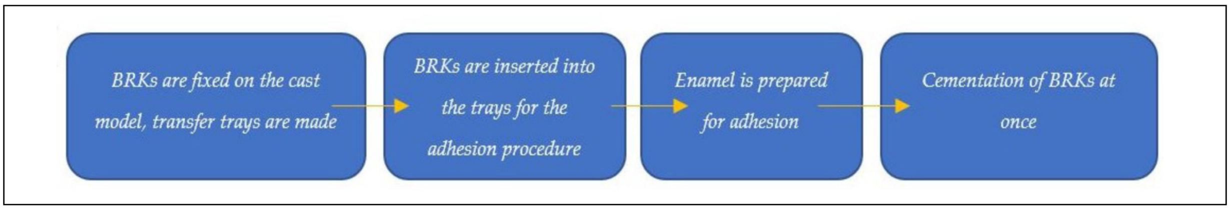

Figure 3. IBB phases.

cular, several studies[25,27,28] compared the existing bonding systems, i.e., HCR, Chemically Cured Resins (CCR), and Light Cured Resins (LCR). The results showed that HCR recorded a higher rate of bond failure than CCR and that LCR registered outcomes that were similar to DBT.

In 1991 a new group of BRKs was designed to reduce the clinicians' chairside time: the Adhesive Precoated Brackets (APC) with resin on their base[30]; these BRKs, however, did not show significative differences in failure rate when compared with non-coated BRKs (NC)[15].

Later on, in 1999, Sondhi[31] introduced a new bonding system for extraoral procedures: this technique en-tailed the addition of 5% of silica filler to reduce the imperfection of the BRKs' bases and the enamel sur-face[31]. This system did not show better results compared to the DBB light-cured system[27]. However, the new protocol was gradually gaining ground, as evidenced by the 2002 report of Keim et al[32]; indeed, it reported that, although more than 90% of clinicians continued to use the old system, the employment rates of IBB and glass ionomers were higher than in the previous report from 1996[32].

More substantial changes occurred when the BRK bonding system met the new technologies of the digital world available to orthodontics. For instance, a new approach that connects the IBB with Computer-Aided Design e Computer-Aided Manufacturing (CAD/CAM) technologies was designed and performed in 2006[33]. The first step of this procedure is the digitalization with a 3D laboratory scanner of the dental impression: on the digital record obtained, through dedicated software, the clinician performs the virtual BRK placement (VBP) with high accuracy (Figures 4 and 5); at this stage, individual 3D transfers are printed to fix the brac-es intraorally[34-36].

In 2010 another virtual procedure was introduced: the stereolithography technique, which produces transfer trays described as "jigs"[37]. The effectiveness of this procedure was reported already in the same year by Son et al[38] in a case study, where the clinicians described how the use of the virtual orthodontic system helped them to obtain an acceptable outcome in the case of mild crowding treated without extraction[38].

The possibilities of VBP at that stage were undoubtedly worthy of exploration, but this new system also raised non-secondary questions. For instance, studies[39] highlighted that at an early stage, VBP was less accu-rate than the previous techniques, because it was difficult to map the tipping of dental cusps during the vir-tual placement: this was a big issue since the tip of dental cusps is an important point of reference for ortho-dontists in a good BRKs placement. However, it was observed that appropriate software could help over-come this problem. A more important issue is the human factor: indeed, several studies[38] raised the

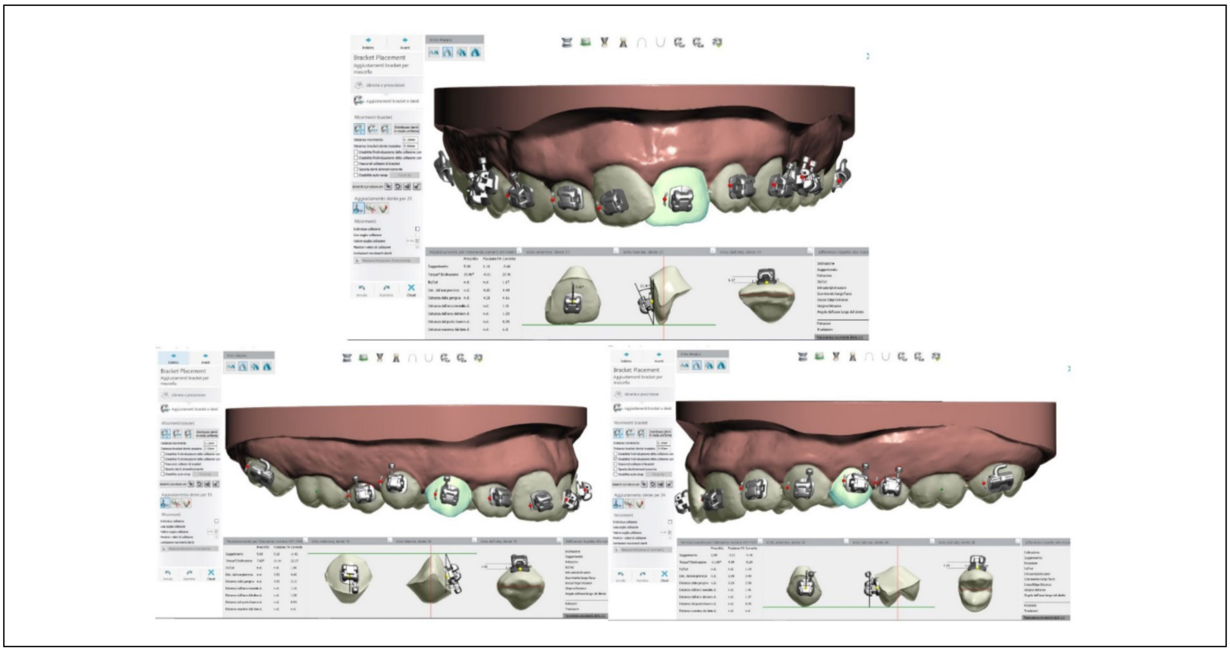

Figure 4. Virtual bracket placement (VBP) of the upper arch.

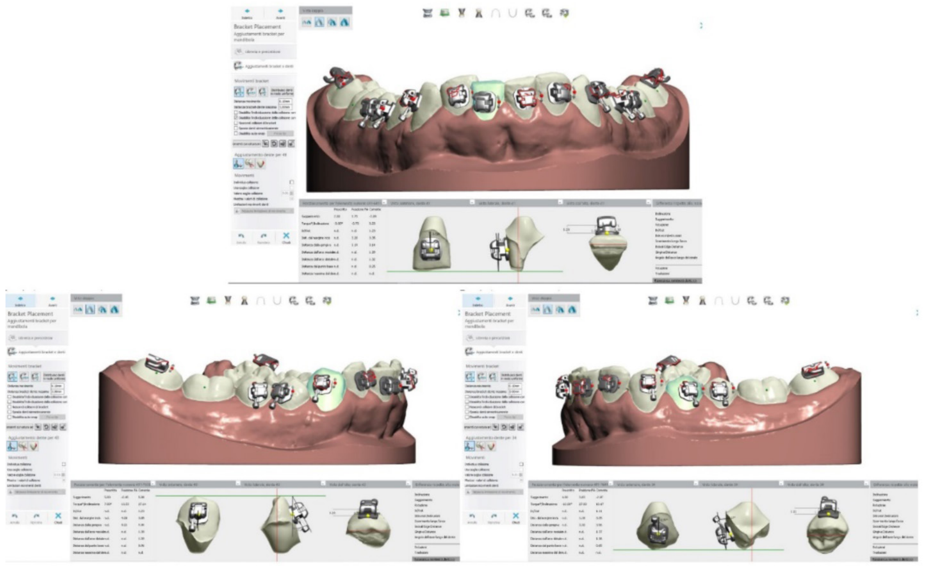

Figure 5. Virtual bracket placement (VBP) of the lower arch.

question of whether the VBT could be transferred with no margin of error in the mouth or not.

More recently, El-Timamy et al[40] introduced a new IBB technique with special consideration of root axes: by positioning the BRKs taking into account the root axes, the clinicians aimed to correct parallelism of the teeth roots at the end of the orthodontic treatment. In order to achieve this purpose, they used 3D images to separate BRKs in the BRK kit from Cone Beam Computed Tomography (CBCT) scanning. These images were converted into stereolithography files for 3D printing and computer-aided manufacturing. At the same time, they entered the CBCT scanning of the patient into the software Mimics: the image of the tray ob-tained from CBCT scanning and transformed into a stereolithography file was printed in 3D for the IBB procedure[40]. This protocol was quite well received since it allowed the orthodontist to position the BRK cor-rectly by visualizing each tooth's crown and root simultaneously[41].

In the contemporary landscape, the available technologies are numerous and in rapid and constant evolution. A recent study by Tarraf and Ali[42] considered it, particularly through an analysis of the application of digital planning at various levels in orthodontics. This study[42] highlights that CAD/CAM technologies are the most used at present in dental alignment treatments, including the Incognito system (3M Company, Saint Paul, Minnesota, United States) for lingual appliances and the Insignia by ORMCO (Orange, California, United States) system, which entails customized labial appliances which are indirectly bound[42].

Regarding the effectiveness of the DBB and IBB systems, several more studies[43] were performed during the first decades of the 2000s: at present, many types of research showed that the two approaches are achieving equivalent results in terms of effectiveness. In 2006, for instance, a comparative study performed by Linn et al[30] highlighted that there was no significant difference in mean bond strength between brackets bonded to teeth using two indirect-bonding material protocols, a chemical-cured primer with a light-cured adhesive and a light-cured primer with adhesive respectively, and a direct-bonding technique, performed with a light-cured adhesive and primer; furthermore, all the three groups tested provided over a 90% survival rate at normal masticatory and orthodontic force levels.

Already in 2004, on the other hand, a *in vivo* and *in vitro* study by Polat et al[44] had evaluated the shear bond strengths and the bond survival of indirect bond resins compared to the direct bond procedure, detecting no significant differences neither in the *in vitro* protocol nor in the *in vivo* analysis, which was carried out nine months after the application of the BRKs. It is worth remembering that a systematic review[45] comparing the bonding failures of orthodontic brackets bonded by indirect or direct techniques was performed by Dos San-tos et al[45] in 2022.

This study showed that at present, although in the first period, bonding techniques result similarly concerning adhesion failures, in an interval of 12-15 months the DBB technique has a lower failure rate than the IBB technique.

Materials and Methods

Protocol of Review

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were fol-lowed and the review protocol was registered at PROSPERO under the unique code 403752[46].

Search Processing

A literature search on PubMed, Scopus, and Web of Science databases was performed in a period from Jan-uary 1, 2013, up to April 6, 2023, with English language restriction. The search strategy was built using Boolean keywords: "orthodontic bracket* AND (bonding OR placement)" (Table I).

Inclusion Criteria

The articles were selected using the following inclusion criteria: (1) *in vivo* studies, (2) *in vitro* studies, (3) studies that investigated comparison between direct and indirect orthodontic brackets bonding, (4) clinical trials, prospective, retrospective, and observational studies and (5) full text available. Studies that did not meet the above criteria were excluded.

The review was conducted using the PICOS criteria:

- Participants: both adults and children who required multibrackets.
- Interventions: indirect bonding.
- Comparisons: direct bonding.
- Outcomes: accuracy of bracket positioning, chairside time, and bonding failure.
- Study: randomized clinical trials, retrospective and observational studies.

Table I. Search strategy.

Articles screening strategy
Keywords: A= Orthodontic bracket*; B= bonding; C= placement Boolean indicators: A AND (B OR C) Timespan: 2013-2023 Electronic databes: Pubmed, Scopus, WOS

Exclusion Criteria

The exclusion criteria were as follows: (1) no-English language, (2) studies that did not compare direct and indirect orthodontic bonding, (3) reviews, comments, books chapters, letters, case reports, (4) no abstract available and (5) no full text available.

Data Processing

Three reviewers (M.C., A.P., and N.D.L) searched the databases to collect the studies and evaluated their quality independently, according to selection criteria. The selected articles were downloaded into Zotero (Vienna, Virginia, USA) (version 6.0.15). Any divergence between the three authors was resolved by consulting a senior reviewer (F.I.).

Results

The electronic database search identified a total of 3,820 (PubMed N = 1,332, Scopus N = 1,267, Web of Science N = 1,221).

After duplicate removal, 1,976 studies underwent title and abstract screening. In total, 1,960 papers were removed after the screening, because 1,949 were off-topic and 11 were reviews, leading to 16 records being selected. Subsequently, 5 papers were eliminated after the full-text evaluation because they did not meet the inclusion criteria, and after eligibility, 11 studies3,47-56 were selected for qualitative analysis. The selection process is shown in Figure 6. The studies' characteristics are described in Table II.

Discussion

This article is reviewed at a comparative level of direct DBB technique and IBB technique in the fixed ap-pliance. The parameters evaluated were: BRK placement accuracy, chairside time, oral hygiene, and bond detachments in both direct and indirect techniques.

Atilla et al[48] observed in their study the records obtained from pre- and post-treatment through quantitative light-induced fluorescence (QLF) in orthodontic patients treated with the IBB technique and orthodontic pa-tients treated with the DBB technique, to assess a lower degree of enamel demineralization and less presence of white spot lesions (WSLs) in the group treated with IBB technique. Nevertheless, in patients treated with the IBB technique, the composite was fluid and not traditional as in those treated with the DBB technique[57-59].

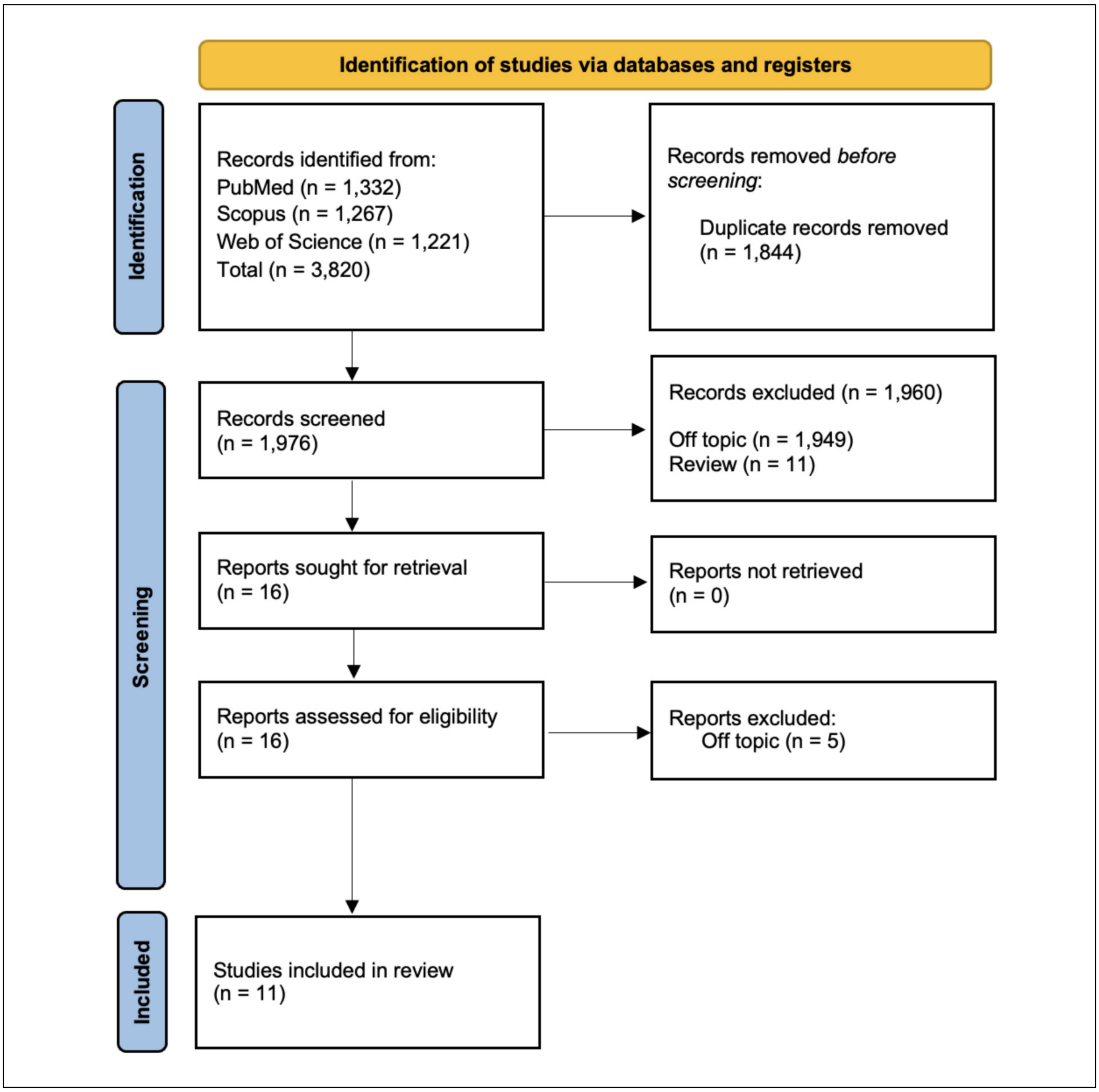

Figure 6. PRISMA flow diagram.

In the literature, the advantages of the DBB technique and IBB technique to place BRKs were compared, and these investigations have been cross-sectional or retrospective in nature, instead, Murakami et al49, de-signed a prospective study to evaluate the relative efficacy and safety of the direct and indirect bonding techniques in fixed orthodontic treatment from a comprehensive perspective[60-62].

The study of Bozelli et al[3] compared the time required for the DBB technique and IBT technique approach-es. The duration of the clinical (DBB and IBB) and laboratory (IBB) stages, as well as the frequency of loose BRK during a 24-week follow-up, were assessed[3]. For this study, 17 patients – 7 men and 10 women – who needed orthodontic treatment and had a mean age of 21 years were chosen. There were 304 BRKs used in all (151 DBB and 153 IBB). Both groups employed the same bracket style and bonding substance[3]. The Wilcoxon non-parametric test was used to statistically analyze the data and the 5% threshold of significance. The IBB approach required more time than the DBB, according to the findings, while taking into account the overall amount of time (p = 0.001)3. However, the IBB required less time than the DBB (p = 0.001)

Table II. Descriptive summary of item selection.

Authors (Year)	Type of the study	Aim of the study	Average time of treatment	Materials and Methods	Results
Menini et al[47], 2014	Clinical longitudinal study	Investigate the efficacy of IBB technique by considering the detachment of BRKs that occurred during the treatment.	15 months for both groups.	Stainless steel BRKs, molar tubes, and the same adhesive system was used for both groups. 1,248 BRKs were positioned. 792 BRKs with the DBB technique and 456 BRKs with the IBB technique.	No significant differences were observed in the total bond failure rate between the IBB technique and the DBB technique.
Atilla et al[48], 2020	Two-arm parallel trial	Investigate the enamel demineralization and the white spot lesions (WSLs) on in IBB technique with flowable composite adhesive *vs.* demineralization in DBB technique with conventional composite adhesives.	1.22 ± 0.31 years in group 1, 1.75 ± 0.45 years in group 2.	Photographs, dental models, and radiographs were taken pre-treatment and post-treatment for all patients.Enamel demineralization and WSLs were monitored pre- and post- treatment using using quantitative light-induced fluorescence (QLF)	In group 1 bonded with the IBB technique, there was a reduced WSLs formation.
Murakami et al[49], 2016	Prospective randomized	Investigate total treatment time, occlusal index, unease at bonding, oral hygiene after bonding, chair time, and BRKs detachment from a tooth in patients treated with the IBB technique and with the DBB technique.	22.91 ± 4.35 months in group DBB, 14.23±5.02 months in group IBB.	In the DBB group, the BRKs will be directly placed on the enamel surface by the operator; in the IBB group, the BRKs will first, be located and attached to a plaster model of the patient teeth, and then they will be transferred in a tray to the patient's mouth.	The study was planned to prospectively evaluate the relative of the IBB technique and DBB technique.
Bozelli et al[3], 2013	Prospective study	Evaluate time of DBB technique and IBB technique.	Not specified	17 patients who needed orthodontic treatment were chosen. 304 BRKs were employed (151 BRKs in DBB and 153 BRKs in IBB). The bracket style and bonding substance were the same in both groups. Wilcoxon non-parametric test with a 5% level of significance was used to statistically analyze the data.	The IBB technique required more time than the DBB technique ($p = 0.001$). The time spent during bracket positioning in the laboratory and the clinical session for the IBB technique compared to the clinical procedure
Aboujaoude et al[50], 2022	Clinical trial	Determine whether there are any statistically significant differences between the digital indirect placement techniques of two different BRK types and direct placement approaches.	Not specified	Digital impressions were used to scan a patient's maxillary arch. 20 practitioners used 40 resin copies of this model. An indirect bonding of the identical case with the digital impression was placed on the patient's CBCT (cone-beam computed tomography). Then the directly bonded models were demounted, scanned, and superimposed onto the indirect models.	The differences in height between the direct and indirect approaches were negligible. Self-ligating BRKs significantly differed in height from ordinary BRKs.

(Table continued)

Table II *(continued)*. Descriptive summary of item selection.

Authors (Year)	Type of the study	Aim of the study	Average time of treatment	Materials and Methods	Results
Czolgosz et al[51], 2021	Randomized controlled trial	Evaluate instant BRK debonding and cost mimization, time for BRK bonding using direct or computer-aided indirect bonding.	Not specified	With a split-mouth design and computer-aided direct and indirect bonding methods, consecutive patients were randomly assigned to one of two groups (blocks of four, online-generated sequence): group 1 (upper right and lower left quadrants: indirect bonding; upper left and lower right quadrants: direct bonding) or group 2. (Opposite situation).	The total bonding time (28 min 14 sec) was longer for computer-aided indirect bonding than for direct bonding (p=0.001) when the time for digital BRK installation was added. With the indirect bonding method, 14 brackets (5.1%) were lost (p = 0.0001). Computer-aided indirect bonding was more expensive than direct bonding, according to a cost-minimization study.
Yildirim et al[52], 2018	Randomized clinical trial	Confront the outcomes of DBB technique and IBB technique in orthodontic treatments.	Group A: 11.4 ± 2.4 months,group B: 12.0 ± 3.1 months.	A total of 420 BRKs were bonded in each group. Clinical time, treatment time, plaque accumulation, formation of WSLs, and bond failure were evaluated.	The clinical time and laboratory time in group A were longer than the only clinical time in group B No differences were found between the two groups in terms of treatment time, plaque accumulation, and formation of WSLs and bond failure.
Demirovic et al[53], 2018	*In Vitro* and *in vivo* study	Compare the shear bond strength (SBS) and Adhesive Remnant Index (ARI) in the IBB technique and DBB technique.	Not specified	*In vitro*, each tooth is placed in separate acrylic blocks, cleaned, etched with 37% phosphoric acid gel for (30 s), flushed (5s), and dried (10s). Premolar BRKs Discovery Roth 0.022 were bonded with Transbond XT and LED curing was performed for 20 s. In the indirect technique group, impressions of teeth were taken, the BRKs were placed on plaster models and cured for 10 minutes. The same protocol was used for the vivo study in the DBB technique and IBB technique.	There were similar results in terms of SBS and ARI in the DBB technique and IBB technique.

(Table continued)

Table II ***(continued).*** Descriptive summary of item selection.

Authors (Year)	Type of the study	Aim of the study	Average time of treatment	Materials and Methods	Results
Flores et al[54], 2015	*In Vitro* study	Compare the shear strength (SBS) and adhesive remanence index (ARI) with Transbond (XT) and Beauty Ortho Bond (BO) using the IBB technique and DBB technique.	Not specified	Group, I = TX/DBT; Group II = TX/IBT; Group III= BO/DBT; Group IV= BO/IBT Groups V, VI, VII, and VIII were identical to Groups I, II, III, and IV, respectively, but were also subjected to thermal 1,500 complete cycles between 5 and 55°C in distilled water, for 1 minute. In Group I (TX/DBT) and Group II (TX/IBT), teeth were etched with acid (35% H 3 PO4) for 30 s, and washed for 20 s with an air-water spray. In group III (BO/DBT and group IV BO/IBT, teeth were conditioned with self-etching primer. Transfer trays for IBT were made from additional silicone. All groups were light-cured by LED curing light for a total of 30 s. The enamel surfaces after bracket removal were examined. The SBS was tested on a universal testing machine at a crosshead speed of 0.1 mm/min. The ARI on the enamel surface was examined under a binocular microscope using 4× magnification.	In IBB groups, SBS values resulted significantly lower than DBB groups. Thermal cycling decreased the SBS values of all groups.
de Oliveira et al[55], 2019	Vitro study	Confront the precision of virtual and DBB techniques in orthodontics.		280 teeth, with 10 orthodontists in both group I and group II. A single dental mannequin, in normal occlusion was digitized, 10 sets of digital models, and 10 sets of solid models were obtained. orthodontists performed the DBB technique on solid models and then at 15-day intervals the virtual bonding through virtual software. The solid the model was scanned and compared to the ideal bonding position. The virtual bonding was compared to the ideal bonding position.	Virtual bonding allowed accurate placement of BRKs, with significant differences in the vertical ($p < 0.001$) and horizontal dimensions ($p < 0.001$).
Panayi et al[56], 2020	Prospective cross-sectional comparative study	Compare the accuracy in the three-dimensional world of direct bonding with virtual indirect bonding using eye vision or loupes on orthodontic patients	Not specified	One dentist applied brackets directly to 18 patients (298 permanent teeth). Then, to improve the BRK location, loupes were used. Before direct bonding, following direct bonding, and following the usage of loupes, intraoral scanning of the dental arches was carried out. The three scans were superimposed, measuring in the media-distal, occlusal-gingival, and mesio-distal angulation.	Virtual indirect bonding was more precise in BRK location for all teeth and the majority of the measured tooth groups. Comparing bonding accuracy with direct eyesight, using loupes did not considerably improve it.

when simply considering the clinical phase. The amount of time required for the laboratory placement of the BRKs and the clinical session for IBB in comparison to the clinical process for DBB was not statistically different (p = 0.910)3. Furthermore, there was no difference between the two groups in terms of the occur-rence of loose BRKs. Since the clinical session was shorter and the overall time required for the laboratory placement of the BRKs, and the clinical process was comparable to that of the DBB technique, the IBB technique may be recommended as a legitimate clinical technique[3,63-66]. In contrast, the study by Yıldırım and Saglam-Aydinatay[52] assessed that in the IBB technique, although the clinical time was less, laboratory time was added, and thus the IBB technique needed a longer time than the DBB technique[52]. In this study, they contrasted how direct and indirect bonding approaches affected the course and results of orthodontic treatment. The bonding of BRKs was done either indirectly (group A, n = 15 patients) or directly (group B, n = 15 patients) on thirty patients. The American Board of Orthodontics Objective Grading System was used to evaluate the orthodontic treatment results. Both the clinical and overall times were considerably longer in group A than in group B, with the clinical time being significantly higher in group B. In the clinical stage, indirect bonding was substantially quicker than direct bonding, producing better marginal ridge and overall scores. Similar rates of plaque buildup, development of white spot lesions, bond failure, treatment time, and further archwire bending and bracket repositioning were seen with both procedures[52].

Aboujaoude et al[50] compared the two placement procedures' accuracy utilizing two distinct BRKs types –conventional twin BRKs and self-ligating BRKs – in the maxillary arch to determine if the type of BRKs in-fluenced positioning precision. The changes in height between the direct and indirect approaches were not substantial. Self-ligating BRKs have a substantially larger height difference than traditional BRKs. Signifi-cant variations in mesiodistal placement were seen for teeth 13 and 15 with self-ligating BRKs (p = 0.019 and 0.043, respectively)[50]. Additionally, the deviation was higher for these categories. In terms of angula-tion, the distinction was significant on tooth 12 with traditional BRKs (p = 0.04) and on teeth 12 and 22 with self-ligating BRKs (p = 0.09). Direct bonding and indirect bonding did not differ significantly in any im-portant ways. There were only noticeable changes in the laterals for angulation and teeth 13 and 15 for mesiodistal centering. Since self-ligating BRKs exhibited a wider deviation range than traditional BRKs, the kind of bracket appears to have an impact on positioning accuracy[50].

According to de Oliveira et al[55], virtual bonding software can increase the precision of BRKs placement. They compared the accuracy of virtual and traditional direct bonding of orthodontic equipment. In compari-son to the direct technique, their study found that the accessory's virtual placement increased the vertical di-mension's accuracy by approximately double when clinical constraints were considered[55].

With computer-assisted bonding, common deviations from optimum placement in the vertical dimension and inaccurate height definition for each unique case and problem type can be reduced in each case. As a re-sult, recording the changes required for each tooth movement under these conditions enables preparation by running several simulations of the treatment outcome. It may be best for orthodontic practice to place the ac-cessories according to the demands of the particular patient rather than the predetermined prescription. Fur-ther research is required and ideally would involve prospective randomized controlled trials for CAD/CAM orthodontic appliances, although this technology is still extremely costly. Furthermore, a substantial collabo-ration between orthodontists, laboratory specialists, dental schools, and industries is necessary to find workable solutions and make prospective improvements to the virtual bonding protocols[55].

In the randomized controlled trial of Czolgosz et al[51], the bonding times for BRKs utilizing direct bonding were compared with computer-aided indirect bonding evaluating BRKs debonding right away and cost con-tainment. The main result was the time difference involved in bonding BRKs[51]. The secondary result was the instantaneous debonding of BRKs (at the bonding appointment). The duration of the clinical bonding technique and the implantation of digital BRKs were both timed. The results were assessed in blindness, and Friedman's ANOVA test was employed to evaluate the variations in bonding time. The immediate debond-ing was compared using the Chi-square test. A cost-cutting analysis was conducted[51].

Computer-assisted indirect bonding required much less clinical chair time (12 minutes and 52 seconds) than direct bonding (16 minutes and 47 seconds) to bond a half-mouth (p = 0.001). When calculating the digital BRK's time. In comparison to the DBB technique, the IBB technique took longer to complete (28 minutes and 14 seconds) ($p = 0.001$). With the DBT, there was not a single instant debonding, however, with the DBT, 14 BRKs (5.1%) were lost ($p = 0.0001$)[51].

An analysis of costs found that the computer-aided IBB technique was more expensive than the DBB tech-nique. In comparison to the DBB technique, computer-aided indirect bonding required much less time in the clinical chair. However, compared to the DBB technique, the entire bonding time for computer-aided indi-rect bonding, including digital bracket installation, was longer[51]. There was a great deal of more immediate debonding compared to direct bonding with computer-aided indirect bonding. Computer-assisted indirect bonding has occasionally turned out to be more expensive than the DBB technique[51].

Another study[56] assessed the accuracy of the DBB technique and IBB technique in three-dimensional space utilizing eye vision or loupes on orthodontic patients. In this research, BRKs were applied directly to 18 patients. Then, to enhance the BRK location, loupes were utilized. Before bonding, after direct bonding, and after the direct bonding, intraoral scanning of the dental arches using loupes on the initial intraoral scan made before bonding, an orthodontic program was utilized to virtually indirectly bind the BRKs[56]. The three scans were superimposed using a three-dimensional mesh processing program, and measurements in the mesiodistal, occlusal-gingival, and mesiodistal angulation were taken. Compared to direct bonding by eye vision or utilizing loupes, the results demonstrated that VBT was more precise in BRKs location for all teeth and most of the tested tooth groupings[56]. Certain teeth and areas of the dental arch in the two direct bonding groups displayed more bonding faults in comparison to virtually indirect bonding. Using loupes did not sig-nificantly increase bonding accuracy compared to direct vision[56]. In comparison to direct vision or direct bonding with loupes, VBT enabled accurate BRKs positioning in the measured dimensions and angulation (Figure 7)[56].

Menini et al[47] studied the bond failure of BRKs with both the IBB technique and the DBB technique. They evaluated 52 patients divided into 2 groups: 33 of them bonded with the DBB technique and 19 of them bonded with the IBB technique. For both groups were used the same stainless steel BRKs and molar tubes 0.018″, 0.025″ and 0.022″ 0.028″ (AO, 1714 Cambridge Avenue, Sheboygan, WI, USA) and the same adhesive system (Transbond XT, 3M, Monrovia, CA, USA). The patients were monitored for 15 months. A total of 1,248 BRKs were positioned: 792 positioned with the DBB technique and 456 BRKs were placed with the IBB technique. In both groups were respectively reported 28 detachments in DBB technique BRKs and 26 detachments in IBB technique were. There was no significant difference in bond failure between the two groups[47].

SBS and adhesive remnant index (ARI) in the IBB technique and DBB technique, were evaluated in a study by Demirovic et al[53]. They conducted a partly *in vivo* and partly *in vitro* study to evaluate differences in SBS and ARI in the two methods DBB technique and the IBB technique. For the *in vitro* study, 60

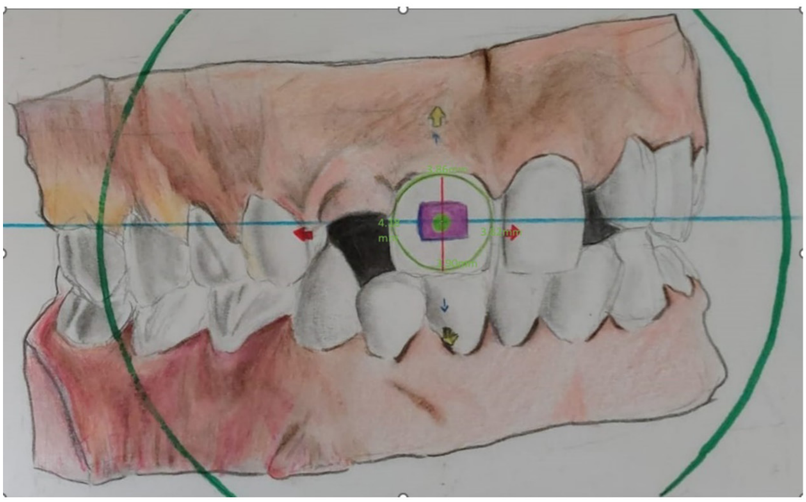

Figure 7. Virtual bracket placement (VBP).

orthodontically extracted maxillary and mandibular premolars with intact buccal surfaces were evaluated and these teeth were used for the DBB technique and IBB technique with Discovery Roth twin brackets. Thirty patients were selected for the *in vivo* study, 15 of whom were treated with the DBB technique and 15 with the IBB technique. SBS was tested by using a universal testing machine Zwick 1435 (Zwick, Ulm, Germany) at a crosshead speed of 0.1 mm/min. Instead, ARI was evaluated with a ZKM 01-250C light microscope (Zeiss, Germany). This study did not reveal any statistically significant differences in SBS and ARI between the *in vitro* and *in vivo* DBT and IBT groups. Therefore, as regards the parameters of SBS and the ARI, the two systems, DBB and IBB techniques, were comparable[53].

Flores et al[54] conducted an *in vitro* study on 96 premolars extracted for orthodontic reasons to compare SBS and ARI of two systems of adhesion of the BRKs to enamel: the first an adhesive system requiring 37% phosphoric acid etching (Transbond XY, TX) while the second, a self-etching adhesive system (Beauty or-tho bond, BO). Both of these systems have been tested for both DBB and IBB techniques, and an evaluation has been made after subjecting the models to 1,500 thermal cycles at a temperature between 5 and 55°C. The ARI of the two adhesion systems was evaluated under the binocular microscope in both direct and indirect bonding. This study showed that both SBS and ARI do not depend so much on the DBB or IBB technique as on the adhesion methods. The SBS is higher with the TX system, which requires etching at 37%, and this is in line with the fact that etching produces porosities on the enamel, which determine a greater adhesion strength with the primer and bonding, but this also determines a higher residual ARI. IBT resulted in lower SBS in both materials, TX, and BO. The thermal cycles decrease the SBS of the two adhesive systems, and in any case, the BO group shows lower SBS values than the TX. Although the BO method presents a lower SBS, the SBS is in any case at the clinical values, so used in combination with the indirect technique, it rep-resents a good compromise because there is a reduced ARI, which prevents enamel demineralization such as white and brown spots[54].

Limitations

This study presents some limitations. The research found 8 studies *in vivo*, 1 *in vivo* and *in vitro*, and 2 *in vitro*. Furthermore, studies were also heterogeneous, and the assessment of the quality of studies was not ap-plicable.

Conclusions

The analysis of the studies examined for this review shows that the correct and proper bonding of the pread-justed orthodontic BRKs for the treatment of malocclusions is very important, so it is the chairside time re-duction.

However, if the positioning accuracy is better in the IBB technique, the time chairside reduction and bond-ing failure are similar in both techniques, in fact, there is not a statistically significant difference.

Due to the digital workflow and the intraoral scanner with dedicated software is possible to make a virtual bracket positioning and transfer in the patient's mouth with transfer trays custom made.

The limit of this digital software is that it cannot correctly identify the dental cusp, which is a very important reference point for the bracket position. Thus, the virtual bracket positioning is less precise in malocclusions with severe crowding.

All orthodontic practitioners hope that in the next future, the digital software will be more precise to aid our procedure of IBB technique.

Authors' Contributions

Conceptualization, A.P., G.M., and M.G.; methodology, A.D.I., N.D.L.; software, A.D.I., A.M.I., and F.I.; validation, S.B., E.M., and G.D.; formal analysis, M.G., and A.P.; resources, I.R.B., G.M., A.D.I., and A.M.I.; data curation, M.C., N.D.L., I.P., and S.B.; writing-original draft preparation, M.C., A.P., and G.M.; writing-review and editing, A.P. C.A., I.P., and M.G.; visualization, N.D.L., C.A., and M.C.; supervision, E.M., A.M.I., F.I., and G.D.; project administration, I.R.B., A.M.I., F.I.; and G.D. All authors have read and agreed to the published version of the manuscript.

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Funding
This research received no external funding.

Data Availability
Not applicable.

Informed Consent
Not applicable.

Ethics Approval
Not applicable.

Conflicts of Interest
The authors declare no conflict of interest.

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