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REVIEW

Indirect Bonding Revisited

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ABSTRACT

In recent years, the popularity of indirect bonding increased due to advantages such as reduction of chair time and enhancement of patient comfort. Although the indirect bonding technique has improved over the years, the literature has shown different techniques of bracket placement; furthermore, new materials were specially developed for this technique. The aim of this article is to provide a review of the literature, advantages, disadvantages, and laboratory and clinical stages of the indirect bonding technique.

Keywords: Indirect bonding, bonding systems, orthodontics indirect technique

INTRODUCTION

Indirect bonding was developed by Silverman and Cohen (1) in 1972 to reduce clinical time and to enhance patient comfort. In this method, they used cement for attaching brackets to the stone model, a sealant as a clinical adhesive, and thermoplastic trays for the transfer of the brackets. In 1979, Thomas (2) invented "custom composite base technique," which is still the most widely accepted technique currently used for indirect bonding. In this technique, Thomas used a chemically-cured resin for attaching the brackets in a laboratory and a universal and a catalyst resin as the clinical adhesive. The major complication of the Thomas technique is that the polymerization of the chemical resin starts in the patient's mouth, which is problematic in terms of time. If the transfer tray was removed before the completion of polymerization, bracket failure can be seen, and if the tray was left in the mouth for too long, this can disrupt the patient comfort. To solve this problem, the Thomas technique was modified; the universal and catalyst resins were mixed outside the mouth and directly applied to the teeth and custom base (3). With the modified Thomas technique, indirect bonding achieved similar bond strength values compared with direct bonding.

In the previous literature, chemically-cured resins were usually used as clinical adhesives for indirect bonding. Apart from these resins, glass ionomer cements, acrylic epoxy adhesives, and cyanoacrylates were also used (4-6).

Read and O'Brien (7) used light-cured resins for indirect bonding in 1990, and with the advantages of these resins, the indirect bonding technique was further enhanced.

In 2002, Miles (8) used a flowable composite in indirect bonding. The most important advantage of this resin was to fill the voids of the custom base with its favorable viscosity.

With the advancement of technology, computers entered the practice of orthodontics, thereby enhancing the indirect bonding technique. Several companies offer three-dimensional computer-aided design and computer-aided manufacturing (3D CAD-CAM)-generated methods for the fabrication of indirect bonding trays. In one of these, Suresmile (Orametrix Inc.; Dallas, USA) system (9), teeth are scanned using an intraoral scanner, and computer generated 3D images are produced. These 3D images are used for digital set-up, and the brackets are placed in appropriate regions of the teeth. The customized transfer trays for indirect bonding and a customized archwire are prepared. Another popular 3D indirect bonding system is Insignia (Ormco Corp.; Orange, CA, USA)

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(10). In this system, the 3D images of the patients are used for the digital set-up, the CAD-CAM technique is used for design, and customized brackets are produced. Single tooth transfer trays are also produced with the help of computers, and according to physicians' requests, the transfer trays are usually combined to include three or four teeth.

In addition, there are some indirect bonding systems for lingual orthodontics. In these systems, there are customized brackets, transfer trays, and arc-wires. Incognito (3M Unitek; OH, USA) (11), Harmony (American Orthodontics; Sheboygan, Wisconsin, USA) (12), and E-Brace (Guangzhou Riton Biomaterial; China) (13) are some of the examples of these systems.

Advantages of Indirect Bonding

1. Shorter bonding time: No time is spent to decide the location of the brackets during bonding (14). A study that compared the time spent for indirect and direct bonding of both jaws (included all the molar teeth) showed that the total time spent for bonding reduced by 30 min during indirect bonding (15).
2. Easy adjustment of overcorrection: Correction of the rotation an important issue in orthodontics. It is difficult to adjust the amount of overcorrection with direct bonding. The evaluation can make according the situation at the beginning of the treatment and millimetric adjustments of bracket position can made with the indirect bonding technique (16).
3. Adjustment of resin thickness: In some of the areas, especially in the lower anterior teeth, the different thickness of the resin can cause problems in the 2nd order alignment. In later stages of the treatment, contact problems can occur and in–out problems can develop. In the indirect bonding technique, the thickness of the resin can be adjusted to be equal for each tooth right from the beginning of the treatment (17).
4. Modification of the bracket position according to the patient's need: Especially in deep-bite cases, it is important to adjust the bracket position right from the beginning of the treatment for stable results. In the indirect bonding technique, it is easier to prepare and measure the vertical bracket positions to open the bite (16).
5. Ease of working with ceramic brackets: It is very difficult to reposition the ceramic brackets due to their adhesion properties, and it is easier to determine the correct position with the indirect bonding technique at the beginning of the treatment (14).
6. Increasing the stability of the treatment: The most important goal of orthodontic treatment is to obtain permanent results. The periodontal fibers reorganize at the beginning of the treatment with the indirect bonding technique, and this could reduce the risk of relapse (18).
7. Increasing patient comfort: Shorter duration of bonding increases the compliance of patient and also reduces contamination by saliva (14).
8. Protecting ergonomics of the clinician: Shorter bonding duration minimizes the degradation of the postural position (15). Furthermore, with shortened working hours, physician's stress can be reduced.

Disadvantages of Indirect Bonding

1. There is an additional laboratory procedure in the indirect bonding technique.
2. Laboratory stage increases the cost of the technique (19).
3. It is important to work precisely in the laboratory and clinical stages (2).
4. There is a learning curve (19). Therefore, it takes time to correctly and efficiently apply the technique.
5. If the transfer tray does not adapt correctly to the mouth, brackets cannot be transferred to the teeth with precision.
6. If the amount of the clinical resin applied is more than the adequate amount, there can be excessive resins around the brackets, and this condition deteriorates the patient's oral hygiene (20). To prevent these, residues can be cleaned using a scaler or a micromotor with a carbide bur.
7. It is difficult to bond brackets to teeth with a short crown length (2).
8. If adhesives are not suitable for the indirect bonding technique, the shear bond strength (SBS) and success of the technique can be reduced (21).

Laboratory and Clinical Stages of Indirect Bonding

Laboratory stages

1. Impressions can be taken with alginate or two-phase silicone impression materials. Hard stone models are obtained and dried for at least a night.
2. The proper location of the brackets is marked with the aid of a fine-tipped pencil and a bracket placement gauge (22). First, the vertical lines, then the horizontal lines, are drawn (Figure 1).
3. A layer of separating medium is applied with a brush and completely dried.
4. According to the clinician's preference, a chemically-cured, a thermally-cured, or a light-cured resin can be used for the bonding of the brackets to the casts (Figure 2). Excessive resin must be removed, and the resin must be properly polymerized (22).
   If a chemically-cured resin is used, the clinician should wait until the completion of the polymerization according to the

Figure 1. Vertical and horizontal lines for the location of brackets

Figure 2. Bonding of brackets to the stone model

Figure 3. Fabrication of transparent transfer tray

recommendation of the manufacturer. If a thermally-cured resin is used, the model must be put in an oven of 120-170°C temperature for 15 min for the polymerization (2). For the light-cured resin, a light-emitting diode (LED) curing light must be used from mesial and distal surfaces for an additional 10 s for each tooth as the stone model does not reflect light like enamel.

5. Before the fabrication of the transfer tray, a block-out is required for the undercuts. Block-outs can be made with a wax or viscous silicone (20).
6. The clinician can choose to use a thermoplastic or a silicone transfer tray according to the clinical resin. If a light-cured resin is used, a transparent transfer tray is required (Figure 3). After the transfer tray is prepared, the edges should be trimmed. The tray can be divided into two or three parts for easy placement and control. Model and transfer trays should be immersed in warm water for 15 min to dissolve the separating agent, and at the end of this period, the trays could be easily separated from the model.
7. The borders of the tray are cut by 2 mm under the gingival borders. Hard edges are trimmed and corrected with the help of stone burrs and disks (20). Trays are rinsed with water or cleaned in an ultrasonic cleaner.

Figure 4. Sand blasting of composite custom bases

8. Custom composite bases are carefully sanded with 50-μm aluminum oxide particles and cleaned with alcohol (Figure 4) to get rid of oil residues and separating agent residues from the composite base.
9. Trays are dried with air and stored in a dry place until the clinical stage.

Clinical stages

1. Patient's teeth are cleaned with pumice or a fluoride-free paste. They are washed and dried after 37% phosphoric acid is applied for 15 s. Etching must be applied only to the brackets' locations to provide easy flash cleaning around the brackets. Some etching templates called Duran masks can also be used for controlled etching (23). To prepare these masks, the bracket locations are marked with a copying pencil in the stone model and a thermoplastic or an acrylic plate can fabricated. Later, the location of the brackets can be opened with a diamond burr. During bonding, only these areas are etched.
2. After etching, a primer that is compatible with the clinical resin is applied. Trays must be completely fitting and the position of the trays must be confirmed.
3. If the clinical resin is chemically-cured, resin is applied both to the enamel and the custom composite base, and the tray is firmly compressed to the teeth according to the manufacturer's recommendations (Figure 5) (22).
4. If the clinical resin is light-cured, adhesive polymerization must be done using a LED light source from the mesial and distal side of each tooth for 10 s. After removing the tray, an additional 5 s of light-curing can be done from the gingival and incisal side of the brackets to ensure complete polymerization.
5. The transfer tray can be divided into two parts using a scalpel for easy removal from the patient's mouth (Figure 6).
6. The tray is removed using a scaler under the edge of the tray; excessive resins are cleaned using scaler and tungsten-carbide burs (22).
7. Initial archwires can be inserted and ligatured.

Figure 5. Application of chemically-cured resin to the composite custom bases

Figure 6. Division of transfer tray by scalpel

Is the Indirect Bonding Technique as Solid as the Direct Bonding Technique?

***In vitro* shear-bond strength studies**

The strength of the brackets bonded using the indirect bonding technique was investigated in numerous studies. Unfortunately, it is hard to compare these due to the rapid advancement of resin technology. There are two SBS studies by Hocevar and Vincent (24) and Milne et al. (25) in 1988 and in 1989, respectively, with similar results. In both studies, they used a chemically-cured resin (Concise) for direct and indirect bonding groups. They investigated SBS of the groups and found no differences in SBS between the direct and indirect bonding groups.

Yi et al. (26) compared the direct and indirect bonding groups. They used adhesive precoated brackets (APC) and chemically-cured resin (Sondhi Rapid Set) for the indirect bonding technique and APC brackets for the direct bonding technique. Similarly, they found no differences between the SBS values.

Klocke et al. (27, 28) conducted two different studies in 2003. In the first one, they compared SBS values of different custom base resins in the indirect bonding groups with the direct bonding group (27). Chemically-cured (Maximum Cure), thermally-cured (Therma Cure), and light-cured (Transbond XT) resins were used for indirect groups, and there was no difference between the direct and indirect groups. In the second study, three different resin custom bases and clinical resins were compared in the indirect bonding technique, and all the groups had adequate SBS values for clinical use (28).

Polat et al. (29) compared SBS values of three different groups; light-cured resin (Transbond XT) was used for direct bonding in the first group, chemically-cured resin (Custom IQ) was used for indirect bonding in the second group, and chemically-cured resin (Sondhi Rapid Set) was used for indirect bonding in the third group. There was no difference between the first and second groups, but the lowest bond strength was obtained for the indirect bonding group.

In 2004, Klocke et al. (30) conducted another indirect bonding study, and they investigated the stand-by time of the custom composite bases. In the first group, they used chemically-cured resins (Phase II and Custom IQ), and in the second group, they used light-cured (Transbond XT) and chemically-cured resins (Custom IQ). They pre-aged the custom composite bases for 7, 15, 30, and 100 days and compared the bond strength values. They found that the pre-aging up to 30 days had no effect on the SBS values in the indirect bonding technique.

Polat et al. (31) studied the effects of chlorhexidine varnish in the indirect bonding technique. They found that the chemically-cured resin (Sondhi Rapid Set) group in indirect bonding with chlorhexidine varnish had lower SBS values than that in direct bonding with varnish and in indirect bonding with no varnish. As a summary, they did not suggest the use of a chlorhexidine varnish prior to indirect bonding.

Linn et al. (32) compared the SBS values of the direct and indirect bonding groups in 2006. Sixty teeth were divided into three groups; in the first group, light-cured resin (Transbond XT) was used for direct bonding; in the second group, chemically-cured resin (Sondhi Rapid Set) was used for indirect bonding; and in the third group, light-cured resin (Enlight LV) was used for indirect bonding. No differences were found among the groups.

Daubt et al. (33) investigated the effects of thermocycling in indirect bonding, and they found that SBS values decreased with thermocycling.

Thompson et al. (34) investigated the effects of the use of flowable resins in indirect bonding, and they found that flowable resins did not improve SBS values for the indirect bonding technique.

Viwattanatipa et al. (35) evaluated the bond strength of the effect of different surface preparation techniques on survival probabilities of orthodontic brackets bonded to nanofill composite resins in the indirect bonding technique, and they found that the most favorable results were found for aluminum oxide preparation technique.

Kanashiro et al. (36) investigated the influence of different methods of cleaning custom bases on SBS values of indirect bonding. Methyl methacrylate monomers, acetone, aluminum oxide, and washing agents were used for the cleaning. There were no differences between the groups.

Flores et al. (37) compared the bond strengths of the direct and indirect bonding techniques with a self-etching ion releasing S-PRG filler, also they investigated the effect of thermocycling in their study. They found that SBS values were reducing with thermocycling and the SBS values were lower in indirect bonding groups. In addition, the self-etching group had lower SBS values than did the direct groups.

In vitro assessment of adhesive remnant after bracket debonding in indirect bonding

The determination of the remnant adhesive after debonding is useful to select the proper resin in orthodontics and to predict the removal of the composite resin from the enamel. In 1984, Artun and Bergland (38) introduced the adhesive remnant index (ARI) to assess the amount of resin left on the bracket base area. The score was a 4-point scale, which was determined according to the remaining adhesive at the bracket base; 0=all adhesive left on the bracket base, 1=more than half of the adhesive left on the bracket base, 2=less than half of the adhesive left on the bracket base, and 3=no adhesive left on the bracket base. In 1990, Bishara and Trulove (39) developed a 5-point scale for ARI scores: 1=no adherence of composite on the bracket base, 2=less than 10% of composite remaining on the bracket surface, 3=more than 10% but less than 90% of composite remaining on the bracket surface, 4=more than 90% of composite remaining on the bracket surface, and 5=all composite remaining on the bracket base.

In the literature on direct and indirect bonding (30,32,33,35,36), the ARI scores were usually 1 and 2 for most of the resins. This shows us that the fracture type is usually cohesive. Therefore, less resin removal is needed after debonding.

In vitro studies of bracket position accuracy in indirect bonding

Koo et al. (40) duplicated the models of the same patient 19 times, and the first model was ideally bonded by one orthodontist. In the second group, there were nine models bonded to a simulator and nine different orthodontists directly bonded brackets to these models with a light-cured adhesive (Transbond XT). In the third group, there were nine models bonded to the simulator and the same nine orthodontists indirectly bonded brackets with a thermally-cured adhesive (Thermacure). All of the model photos were taken in a standard position, and measurements were taken from the photos. As a result, no differences were found in mesio-distal and angular position of the brackets with both techniques, but the brackets, which were indirectly bonded, were in a more proper position in the vertical dimension.

Aguirre et al. (41) compared bracket position accuracy in the direct and indirect bonding technique. For both techniques, although they achieved similar results, indirect bonding showed favorable results for upper canines and direct bonding for second premolars.

Hodge et al. (42) investigated bracket position accuracy in the direct and indirect bonding technique. They found no difference between the two techniques in the vertical, angular, and mesio-distal position.

Nichols et al. (43) evaluated the repeatability of the bracket position in the indirect bonding technique in 2013. Five experienced orthodontists bonded 10 models at three different times. Models were scanned using an ICAT scanner and superimpositions of the models were made with a computer. They evaluated the differences of the bracket positions. As a result, every clinician's bracket position was consistent in them, and the maximum bracket position difference was 1.25 mm between the groups.

Castilla et al. (44) compared bracket position accuracy of five different types of indirect bonding transfer trays in 2014. The transfer trays consisted of mono-phase silicone, dual-phase silicone, monolayer thermoplastic, double-layer thermoplastic, and a combination of silicone-thermoplastic material. Duplicated 25 models were divided into five groups. Bracket positions were measured using calipers, and it was found that silicone-based trays transferred the brackets more accurately when the error rates were analyzed in all the tray systems.

In Vivo Studies of the Indirect Bonding Technique

In vivo evaluation of bond failures of indirectly bonded brackets

Polat et al. (29) used two different types of chemically-cured resins (Sondhi Rapid Set vs. Custom IQ) in the indirect bonding technique with a split-mouth design. Fifteen patients were included in the study and were followed up for 9 months. Molar teeth were not included in the study. A total number of 295 teeth were indirectly bonded, 13 teeth (4%) were debonded, and no significant difference was found between the groups.

Miles et al. (45) used chemically-cured (Maximum Cure) and light-cured flowable (Filtek Flow) resins in the indirect bonding technique. In all, 112 patients were included in the study and were followed up for 6 months. Molar teeth were also included. The failure rate for chemically-cured resin group was 2.9% and that for the light-cured resin group was 2.4%.

Thiyagarajah et al. (46) used light-cured resin (Transbond XT) for both direct and indirect bonding. Thirty-three patients were included in the study and were followed up for 1 year. Molar teeth were not included in the study. A total number of 273 teeth were indirectly bonded, and the failure rate was 2.2% for indirect bonding. There were no statistically significant differences between the direct and indirect bonding groups.

Deahl et al. (47) compared direct and indirect bonding with a practice-based study. A total number of 1368 patients were included in the study, 772 of these patients were directly bonded and 596 of patients were indirectly bonded by five different orthodontists. The failure rate for the direct bonding technique was 1.17% and that for the indirect bonding technique was 1.21%. There were no statistically significant differences between the groups.

Bozelli et al. (48) compared direct and indirect bonding with split-mouth design in 2012. Seventeen patients were included in the study and were followed up for 6 months. In addition, the total clinical times for both techniques were compared. The failure rate for the direct bonding technique was 4.6% and that for the indirect bonding technique was 6.5%, but there were no significant differences between these groups. The clinical time for indirect bonding was 17 min shorter than that for direct bonding.

Menini et al. (49) compared the failure rates of direct and indirect bonding in 2014. A total number of 55 patients were included in the study, 33 patients were directly bonded, 19 were indirectly bonded, and they were followed up for 15 months. The failure rate for the direct bonding technique was 3.54% and that for the indirect bonding technique was 5.79%, but there were no significant differences between these groups.

Vijayakumar et al. (50) used splint-mouth technique for bonding 30 patients with the direct and indirect bonding technique. They followed up the patients for 6 months, and molar teeth were not included in the study. The failure rate for the direct bonding technique was 8.8% and that for the indirect bonding technique was 10.5%, but there were no significant differences between these groups.

In Vivo Studies That Evaluate the Periodontal Tissues after Indirect Bonding

Zachrisson and Brobakken (21) compared periodontal and plaque indices of patients who were directly and indirectly bonded and found no differences between the groups.

Dalessandri et al. (23) used Duran masks for acid etching to decrease plaque accumulation in indirect bonding technique and compared this technique with the direct bonding technique. Thirty patients were included in the study, who were bonded with the splint-mouth technique, were followed up for 6 months. They found that teeth that were bonded with Duran masks have lower plaque accumulation in the first 4 months of treatment. Furthermore, these teeth have lower white-spot lesions.

CONCLUSION

The indirect bonding technique is a better method for the accurate placement of brackets and for the comfort of both the clinician and patient. For this technique to be a success, it is important to work with precision and experience. With the developing technology and progress in dentistry, the technique will become even easier and simplifier.

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