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Research Article

Bond Failure of 3D Printed Positioning Tray for Fixed Retainers

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Abstract

Objective: This study was carried out to evaluate the bond failure when using the 3D printed positioning tray for bonding the fixed mandibular retainers versus the conventional direct bonding technique method.

Methods: A randomized clinical trial was carried out using the 3D printed positioning tray in the indirect technique and the conventional method in the direct technique, 20 patients were indicated for fixed mandibular retainers, not having any signs of enamel defects or signs of gingival inflammation were assigned in this study. Fixed retainers were placed and boned to the lower anterior segment. In the intervention group, the cast produced from a previously taken impression, was scanned using a desktop scanner to produce the digital model, by which the virtual retainers would be designed using the OrthoAnalyzer software. The tray was printed with a rigid resin to allow ease of insertion and removal. The wire was placed within the 3D positioning tray and then transferred and bonded on the lower anterior segment. The number of detached composite was recorded for the bond failure measurements immediately and after 6 month, in the comparative group, the steps where done as the intervention group, but with the difference in the bonding technique where the retainer was placed directly on the lower anterior segment and stabilized using ligature wire.

Results: No bond failure was recorded immediately in both groups, Total Bond failure count recorded in group I (3D printed positioner) was (1) while in group II (Control) was (2) after 6 months, resulting in 10% bond failure in group I (3D printed positioner) and 20% bond failure in group II (control group).

Conclusion: The bond failure difference between the two bonding techniques was statistically insignificant, between the two groups. Whether immediately or after 6 months.

Keywords: Bond Failure; 3D Printed Positioning Tray; Fixed Retainers

Background

One of the controversial topics in modern orthodontics is retention and as Angle said that "the problem involved in retention is as great as to test the utmost skill of the most competent orthodontist, often being greater than the difficulties being encountered in the treatment itself" [1].

There is a tendency that teeth return to their former positions after orthodontic appliances removal. Relapse prior to orthodontic treatment could be due to orthodontic factors and/or normal age changes. These orthodontic factors can be classified in to periodontal, gingival factors, occlusal factors, factors related to soft tissue pressures [2].

For orthodontic treatment result to be maintained a retention protocol must be followed [3]. Long-term retention is important and permanent retainer is a common way for maintaining the stability of the orthodontic treatment outcome especially in the anterior region.

Over the years techniques for placing a fixed retainer have been achieved whether directly or indirectly [4]. The most common technique used is the direct technique where the composite pads and fixed retainers are bonded on the lingual surface of anterior teeth directly [5].

Kneirim was the first to publish a report using this technique to construct bonded fixed retainers [1] since then many variations in the design of bonded fixed retainers had been introduced. These include different methods of application, wire types with differing diameters [5] as well as different composites.

Bonding lingual retainers directly are not always practical because the available techniques do not aid in stabilizing the fixed retainer wire and also moisture contamination is always a risk which will lead to bond failure [6].

Indirect bonding requires composite preparation on the cast of the patient and production of custom made tray and these custom made trays aid in the placement of retainer in the patient mouth [7]. Indirect methods aids in keeping a moist-free environment but still have some disadvantages, such as lack of control over the composite pad placement leading to bond failure or undesirable flow of adhesive bond to the gingival embrasures.

Regarding the bond failure in a recent systematic review about fixed retainers, wide variations was reported in the risks of bond failure, ranging from 3.5% to 53% for retainers made from metal and from 11% to 51% for reinforced glass fiber retainers. Total failure rate were 37.9% And It was stated that most fixed retainer failures occur during the first the 6 months [8].

Comparable failure rates were reported between direct method with 46.9% bond failure and indirect method with 29.4% bond failure however the difference between the two methods were not statistically significant [9,10].

The last decade have shown a rapid and fast growth in the field of 3D-printing. From the orthodontics point of view, digital models are gaining importance. The major success behind this is most likely the increasing opportunities in improving the workflows in the orthodontics' office - ranging from saving money, effort and costs to optimize the treatment progress and result [11,12].

So present clinical practice needs a much effortless techniques for bonding fixed mandibular retainers.

Materials and Methods

The Research Ethics Committee of the Faculty of Dentistry Cairo University approved this randomized controlled trial. Patient was selected from the outpatient clinic of the Department of Orthodontics, Faculty of Dentistry, Cairo University, the study lasted for 12 months starting from March 2019 till March 2020.

Inclusion criteria:

Patients with well finished orthodontic treatment in need of fixed lingual retainer:

- The presence of full lower anterior segment (4 mandibular incisors and the 2 mandibular canines).
- Non carious, with no restorations, nor fractures, and absence of periodontal disease in these teeth.
- Good oral hygiene.

Exclusion criteria

If any of the previous criteria found.

The following steps was done for each patient:

- According to inclusion and exclusion criteria selection and examination of the patients were done.
- Lower anterior segment was scaled and polished with pumice powder.
- Oral hygiene measures was instructed to the patient.
- Allocation and randomization of the patient to their groups was done.

Treatment group

After orthodontic treatment removal, a modified indirect technique was done for bonding fixed mandibular retainer and the key of modification was the fabrication and designing of 3D printed digital positioning tray for the bonding and stabilizing the fixed retainer, it contained holes for composite pads to be placed directly

and it was designed using 3 shape Ortho planner Software® versing the conventional direct retainer fabrication method using ligature wire.

Lower impression was done for each of the patient and the cast was carefully pored and then scanned by 3 shape desktop laser® scanner for the manufacturing of the 3D digital cast, by the use of 3 shape orthoplanner Software®, the tray was virtually made then printed using formlabs 3 Printer®. The tray was printed by the mean of Anycubic Resin® a hard resin material, permitting the tray and the wire to be intimately adapted to lower anterior teeth. Teeth are etched then isolation. Multistrand Round- Dead Soft Stainless Steel wire was adapted in its indentations in the digital tray followed by Placement of the positioner tray on the prepared teeth as shown in figure 1. 3M ® universal Adhesive bond was used and placed on the prepared teeth then cured. Nano filled 3M® composite (3M Unitek, Monrovia, California, USA) was used in the holes of the printed tray and any excess composite was removed followed by the curing process After curing of the composite the digital tray was then removed from anterior teeth as shown in figure 2, the bond failure was calculated and recorded immediately and after 6 months.

Figure 1: 3D printed positioning tray.

Figure 2: Removal of the tray.

Control group

the conventional steps of direct bonding of fixed mandibular retainer was done to the patients of this group, The retainer wire was stabilized by mean of 1.5" - 2" ligature wire at interdental region of each lower anterior teeth, The retainer wire was then placed on the lingual tooth surface. The short ligatures were passed interdentally in between the anterior teeth. And the Bonding procedure was carried out using 3M® universal Adhesive after etching then Light curing was done, Nano filled composite 3M® (3M Unitek, Monrovia, California, USA) was then used and curing was done for 40 seconds for each tooth, the ligature wires was then removed and pull labially then the bond failure was calculated and recorded immediately and after 6 months.

Results

Immediate bond failure

Total bond failure of 2 groups were calculated immediately presented as failure count & failure percentages as seen in table 1 and figure 3 and 4. No bond failure was recorded immediately in both groups resulting in 0% bond failure as shown in table 1 and figure 3 and 4. The Performed Chi square test revealed insignificant difference between both groups as P-value > 0.05.

Bond failure after 6 months

Total bond failure of 2 groups were calculated after 6 months and presented as failure count and failure percentages as seen in table 1 and figure 3 and 4.

Total Bond failure count recorded in group I (3D printed positioner) was (1) while in group II (Control) was (2) after 6 months, resulting in 10% bond failure in group I (3D printed positioner) and 20% bond failure in group II (control group) with only 10% difference in bond failure between both groups as presented in table 1 and figure 3 and 4. Performed Chi square test revealed in-

significant difference (P > 0.05) between both groups as P-value > 0.05 as presented in table 1.

	Group I (3D printed positioner)		Group II (Control)		Difference		P
	N	%	N	%	N	%	
Immediate	0	0	0	0	0	0	Absolute insignificant
After 6 months	1	10	2	20	1	10	0.54
P	0.31		1.4		0.31		

Table 1: Total count of bond failure of fixed retainers for both groups.
%: Percentage; P: Probability Level.

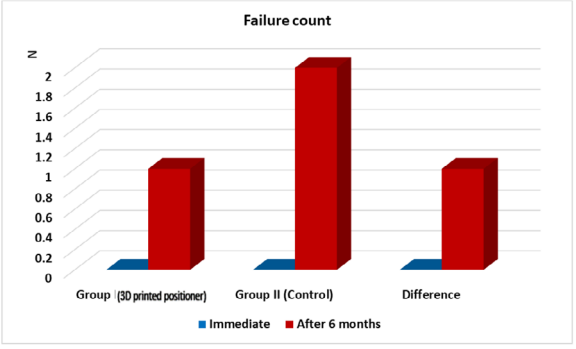

Figure 3: Bar chart represents attachment failure count.

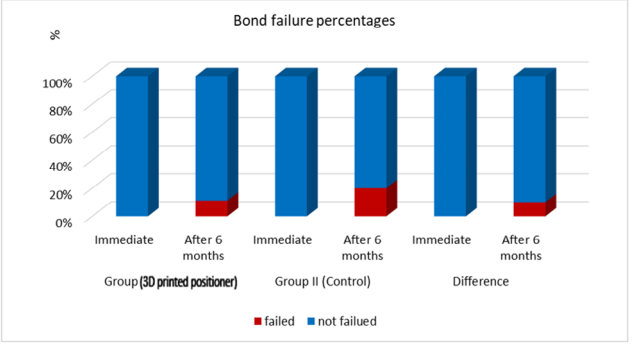

Figure 4: Bar chart represents bond failure percentage.

Discussion

Fixed retention helps in maintaining the stability of the anterior teeth after orthodontic treatment removal by bonding a stainless steel wire on its lingual surface, generally from canine to canine in the mandibular arch, and that is considered an acceptable mean for providing long term retention [13].

There are different bonding techniques to place a fixed lingual retainer. One of the most common technique used is the direct bonding technique where the composite pads are bonded and placed in the lingual surface of lower anterior segment.

Zachrisson., *et al.* was the first who introduced the direct technique [10] by using ligature wire to place the fixed lingual retainer and to help ligated to lower anterior segment and firmly fixing and it keeping the wire stable during setting of the adhesive, after that different modifications have been introduced.

While the indirect bonding technique was introduced in the late 1990s by Bantleon., *et al.* [18] as a time saving alternative to the direct bonding technique. The composite pads patient had to be prepared on the cast of the when using the indirect technique.

Various modifications have been introduced to enhance both direct and indirect bonding techniques, in order to achieve better clinical outcomes. With the evolution of 3D imaging techniques and 3D printing methods, the use of digital models in diagnosis and treatment planning has become a routine in our clinical work.

To our knowledge this randomized clinical trial is considered as the first RCT to compare bonding failure rate of mandibular fixed retainers with direct and 3D printed positioning tray indirect techniques.

In this study, the inclusion criteria were good oral hygiene, no active caries, restorations, fractures and periodontal disease and accordingly the patients were selected to eliminate any factors that might affect the accuracy of the bond failure results.

Fixed retainers were placed only on the lower arch in this study to remove the factors related to biting forces that may change the bond failure results and affect this study.

For the software, designing was done using 3Shape Ortho System as it enabled the overlay of DICOM, cephalometric, and 2D pic-

tures, along with intraoral scans for orthodontic case analysis and planning, treatment simulations, and the design and production of FDA-cleared orthodontic appliances.

In this study also the 3D positioner tray was printed using hard resin, this resin was introduced by Venezia., *et al.* [14] for occlusal splints as it permitted the suitable rigidity needed for adaptation of fixed retainer during its bonding.

For the direct method, the wire was placed to the lower anterior segment by the mean of ligature wire and Zachrisson [16] was the first to introduce this technique who bonded fixed lingual retainer and ligated to the incisors during the bonding.

The fixed retainer was bonded by using Nano filled composite and that was according to Talic (2016) who studied the failure rates of fixed mandibular and maxillary lingual retainers bonded using light-cured nano filled flowable composites over 6 months duration [15].

Moreover, each composite pad was cured for 40 seconds according to Alpöz., *et al.* [16] obviously, the difference in the bonding time would be decreased if one used a shorter polymerization time, but this helped in decreasing the bond failure risk.

Regarding bond failure a recent systematic review about fixed retainers reported wide variations in the risks of bond failure, varying from 3.5% to 53% for retainers made of metal and from 11% to 51% for reinforced glass fiber retainers. Total failure rate of mandibular fixed retainers were found to be 37.9% It was suggested that most fixed retainer failures occur during the first 3 to 6 months [17], whereas the probability of failure significantly drops after a year [8]. Lie Sam Foek., *et al*. [18] found that failure of fixed retainers occurs more often within the first 6 months after placement. Therefore, a follow-up visit at range of 6 months was considered appropriate for this study.

Full mouth scaling and polishing were done to this study participants before to bonding to ensure a healthy periodontium and giving a clean tooth surface ready for bonding. This reduce the chances of bond failure.

Regarding the immediate bond failure zero cases were reported in our study whether in the direct group or the 3D positioning tray group and this differ from Bovali., *et al* [10]. Results where they reported initial bond failure in the in direct group (3 cases of 32 in this study) and explained that d probably due to inadequate placement of the transfer tray and inadequate moisture control.

The 6 month bond failure was found to be 10 percent regarding the 3D printed positioning group and 20 percent regarding direct group and that was lower than with the results of the 6-month risks of failure found by Bovali., *et al* [10]. That were 32% and 24% for the indirect and direct groups, respectively, and also were lower than the 29% and then 47% for the indirect and direct methods previously reported by Taner and Aksul [9] in their prospective study. On the contrary, numbers of failures for direct bonding were fewer to those reported by Lumsden., *et al.* [19] and Dahl and Zachrisson [20] this can be due to the decreased salivary contamination that the positioner provide in the 3D positioner tray group and the type of composite (Nano filled light cured) used which differ from the chemical cured composite used in previous studies.

In our sample, debonding of the mandibular fixed retainer occurred at the adhesive-enamel interface, and no fractures or breakage were recorded within the retainer, findings similar to those of Taner and Aksu [9], Bovali., *et al.* [10] and Lumsden., *et al.* [19] was found. Our failures increased during the first month in both groups and decreased after that. The most commonly debonded tooth was the lower right canine; this finding disagrees with the studies of Bovali., *et al.* [10] and Taner and Aksu [9] where they found the lower right central was the most one found to be debonded according to whom the morphology of the lingual surface of the central incisor can cause an insufficient surface material for bonding of the composite with the enamel surface, subsequently leading to failure. Moreover, debonding in our study could be related to bonding and contamination problem as the lower right canine was the last tooth to be bonded.

Since mandibular fixed retainers are more frequently bonded on all anterior tooth instead of the canines only, patients could to be unaware of a broken composite pad. In our study, patients were not aware of the failure of their fixed retainer at this study. Follow-up of the retainer during the first 6 months after placement seems important to prevent a subsequent relapse problem. The recalls follow up at 6 months appeared to be a convenient protocol, as no

relapse was observed in the mandibular anterior area in any patient. However, a longer follow-up is needed to insure the longevity of the retainer.

Accurate construction of 3D positioning tray and moisture control during the bonding procedure by the orthodontist might decrease the potential of fixed retainer's bond failures.

However, in addition to bond failure, torque differences has been considered as another side effect studied by Renkema., *et al.* [21] with the direct bonding technique after a 5-year posttreatment observation period. Subsequently, it would be important to determine whether similar side effects could be avoided by the use of the indirect bonding technique, since studied this side effect before

A fixed position of the wire inside the 3D positioning tray could ensure the passive application during the bonding procedure. In contrast with the direct bonding technique, the 3D positioning tray ensures the wire stability and passiveness during its fabrication and placement. Because of incorrect placement and patients biting habits 'can also cause torque problems not only inaccurate placement by the clinician. If indirect bonding aids in decreasing torque problems in the long run, indirect bonding could be a good replacement to direct bonding not only so further investigations will be needed.

Conclusion

The bond failure difference between the two bonding techniques was statistically insignificant, between the two groups. Whether immediately or after 6 months.

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