

Modified single rigid vacuum-formed indirect bonding trays for lingual bracket application: a case report

Anh Viet Nguyen^{*} and Anh Thuy Nguyen[†]

Faculty of Dentistry, PHENIKAA University, Yen Nghia, Ha Dong, Hanoi, Vietnam^{*}

Private Practice, Viet Anh Orthodontic Clinic, My Dinh 1, Nam Tu Liem, Hanoi, Vietnam[†]

Lingual orthodontic treatment offers an aesthetic alternative but presents unique challenges in bracket positioning. The present article introduces a modified design and fabrication process for rigid vacuum-formed indirect bonding trays for lingual bracket application. The technique is presented through a clinical case report of an adult patient who presented with bimaxillary dentoalveolar protrusion and managed using lingual appliances, premolar extractions, and mini-screws. The modified rigid vacuum-formed trays enabled the accurate simultaneous bonding of multiple teeth as well as individual teeth. The technique offers several advantages over existing indirect bonding methods, including time-saving, simplicity, easy removal of excessive adhesive, and potential cost-effectiveness. The superimposition of post-bonding scans and the digital orthodontic setup showed high agreement between the planned and actual bracket positions. Additionally, the close alignment between the planned orthodontic setup and the achieved treatment outcome highlights the reliability of the technique for predictable lingual orthodontic treatment. Further clinical studies with larger sample sizes are needed to confirm the effectiveness of this technique. (Aust Orthod J 2024; 40: 40 - 50. DOI: 10.2478/aoj-2024-0020)

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Anh Viet Nguyen: anh.nguyenviet1@phenikaa-uni.edu.vn; Anh Thuy Nguyen: thuyanhhrhm@gmail.com

Introduction

Lingual orthodontic treatment poses unique challenges due to limited direct visualisation, measurement and anatomical variability of the lingual tooth surfaces. To overcome these difficulties, lingual brackets are generally bonded indirectly using ideal setup models.^{1,2} Brackets can be transferred as a group by utilising flexible vacuum-formed or silicone indirect bonding trays^{3,4} or individually using rigid transfer jigs.^{1,5} The group indirect bonding trays and individual transfer jigs can be fabricated indirectly on analog or 3D-printed setup models or directly using 3D printing.⁶

Transferring groups of brackets by flexible trays has the possible advantage of time-saving, cost-effectiveness, and higher transfer accuracy due

to greater accessibility to available anatomical references.³ Hence, flexible trays are generally used for the initial full-arch bracket bonding.^{7,8} The transfer accuracy of double vacuum-formed indirect bonding trays for lingual brackets has been demonstrated to be high in the mesiodistal, buccolingual, occlusogingival, and rotational directions.³ However, flexible trays become less reliable for individual bracket re-bonding due to failures or when dealing with teeth that were not initially bonded due to crowding or displacement.⁴

The present article aims to report a modified design and manufacturing process for rigid vacuum-formed indirect bonding trays for lingual bracket application that further support precise single-tooth bracket attachment. Additionally, the technique's accuracy is



Figure 1. Pre-treatment extraoral and intraoral photographs.

demonstrated through a brief clinical case report of an adult patient presenting with protrusion and managed using lingual appliances and premolar extractions.

Diagnosis and aetiology

A 32-year-old Southeast Asian female patient presented with a chief complaint of dental protrusion. Her systemic medical history was non-contributory. The patient's lower right third molar received endodontic treatment five years previously.

On extraoral examination, the frontal view showed well-balanced vertical proportions with a left-deviated mandible (Figure 1). The lateral view revealed a convex profile, protruded lips, and mentalis strain on lip closure. No signs and symptoms of a temporomandibular joint disorder were recorded.

On intraoral examination, the patient had Class I molar and canine relationships on both sides. Upper incisor proclination was evident and the upper and lower transverse arch widths were within the normal range. Minor crowding was apparent in the lower

arch. The upper dental midline aligned with the facial midline, whereas the lower dental midline had shifted 1 mm to the left.

On lateral cephalometric evaluation, a skeletal Class I sagittal relationship was noted with a normally-positioned mandible and maxilla (SNA: 82.4°, SNB: 78.6°, ANB: 3.8°) and a normo-divergent vertical facial pattern (FMA, 26.3°). Both the upper and lower incisors were proclined (U1-SN: 110.2, L1-MP: 97.8°, interincisal angle: 113.6°). The soft tissue profile was protrusive (upper lip/E-line: 2.2 mm, lower lip/E-line: 4.8 mm) (Table I). The panoramic radiographs showed the presence of all teeth including the endodontically-treated lower right third molar (Figure 2). The patient was diagnosed with bimaxillary dentoalveolar protrusion on dental and skeletal Class I relationships.

Treatment plan

The treatment objectives included upper and lower incisor retraction to improve lip projection, levelling

Table 1. Cephalometric measurements

	Pretreatment	Posttreatment
Skeletal		
SNA (°)	82.4	81.3
SNB (°)	78.6	78.7
ANB (°)	3.8	2.6
FMA (°)	26.3	25.7
Dental		
U1-SN (°)	110.2	100.4
U1-NA (°)	27.8	18.9
U1-NA (mm)	9.8	2.8
L1-MP (°)	97.8	89.0
L1-NB (°)	34.8	24.2
L1-NB (mm)	9.8	4.2
Interincisal angle (°)	113.6	133.9
Soft tissue		
Upper lip/E-line (mm)	2.2	-0.8
Lower lip/E-line (mm)	4.8	0.8

ANB, A point, nasion, B point; FMA, Frankfort mandibular plane angle; L1, lower central incisor; MP, mandibular plane; NA, nasion point A; NB, nasion point B; SNA, sella nasion point A; SNB, sella nasion point B; U1, upper central incisor.

and alignment of both arches, the correction of the lower dental midline, and the maintenance of a dental Class I relationship, plus a normal overjet and overbite.

A surgical treatment option was excluded owing to the normal anteroposterior and vertical skeletal relationships. A treatment plan involving first premolar extractions in both arches was chosen based on the severity of the dentoalveolar protrusion. Additionally, the patient elected to have her third molars extracted owing to repeated inflammation. Lingual brackets were chosen because of the patient's strong desire for aesthetic appliances and the author's preference for fixed appliances in extraction cases.

Indirect bonding procedures

Virtual lingual bracket positioning procedures for rigid vacuum-formed indirect bonding trays were similar to the workflows described in detail in previous studies.^{1,3,4} The patient's intraoral digital impressions were imported into orthodontic design

software (Autolign, Diorco, Korea). A digital orthodontic setup was created, which considered the necessary overcorrection of tip and torque for extraction cases. Lingual brackets were subsequently virtually placed according to a reference plane and a straight arch wire template, which minimised the distances between the brackets and teeth. The lingual brackets were digitally moved along with the corresponding teeth back to the initial malocclusion state (Figure 3).

With double vacuum-formed indirect bonding trays, undercuts below the bracket wings are generally not blocked out to create a secure lock between the brackets and the inner tray soft layers. However, using rigid trays, all undercuts have to be blocked out to allow tray removal after clinical bonding procedures. The blockout process can be performed by several freeware applications (Meshmixer, Autodesk, USA, and Medit Design, Medit, Korea). The block-out angle should be set at 20° for anterior brackets and 45° for posterior brackets so that blocked-out brackets can be three-dimensionally (3D) printed without support placement at a build angle of 180° (Figure 4). The 3D-printing process was performed using a digital light processing printer (Photon D2, Anycubic, China) and a dental model resin (Die & Model 2, SprintRay, USA).

After post-printing processing, rigid indirect bonding trays were vacuum-formed on the printed models using 1 mm thickness hard foils (Biocryl, Scheu, Germany). The trays were cut at approximately two-thirds of the bracket heights to allow easier excessive adhesive removal. Passive self-ligating lingual brackets (0.018" x 0.025", JK-SL, In Tendo, UK) were placed into the trays (Figure 5). Indirect bonding trays are generally sectioned into three-tooth spans to facilitate tray removal. Optionally, a try-in can be performed on study models to check the tray fit. Customised archwire forming procedures remain similar to other digital lingual orthodontic workflows.^{1,4,9}

Following usual clinical bonding procedures, all teeth were pumiced and etched with 37% phosphoric acid (FineEtch, Spident, Korea). An orthodontic adhesive (Transbond, 3M, Minnesota, USA) was applied to the bracket bases and an orthodontic primer (Transbond, 3M, Minnesota, USA) was applied to the lingual tooth surfaces, following which, the indirect bonding trays were placed onto the teeth. Excessive

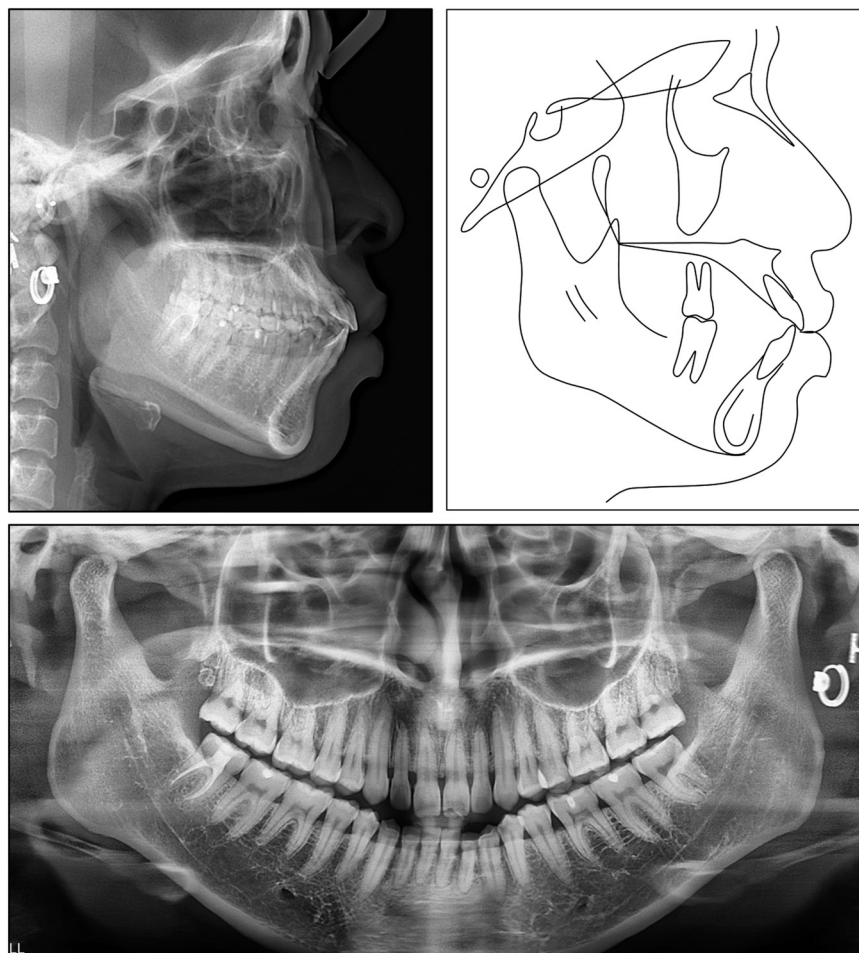


Figure 2. Pre-treatment panoramic and cephalometric radiographs and tracing graphs.

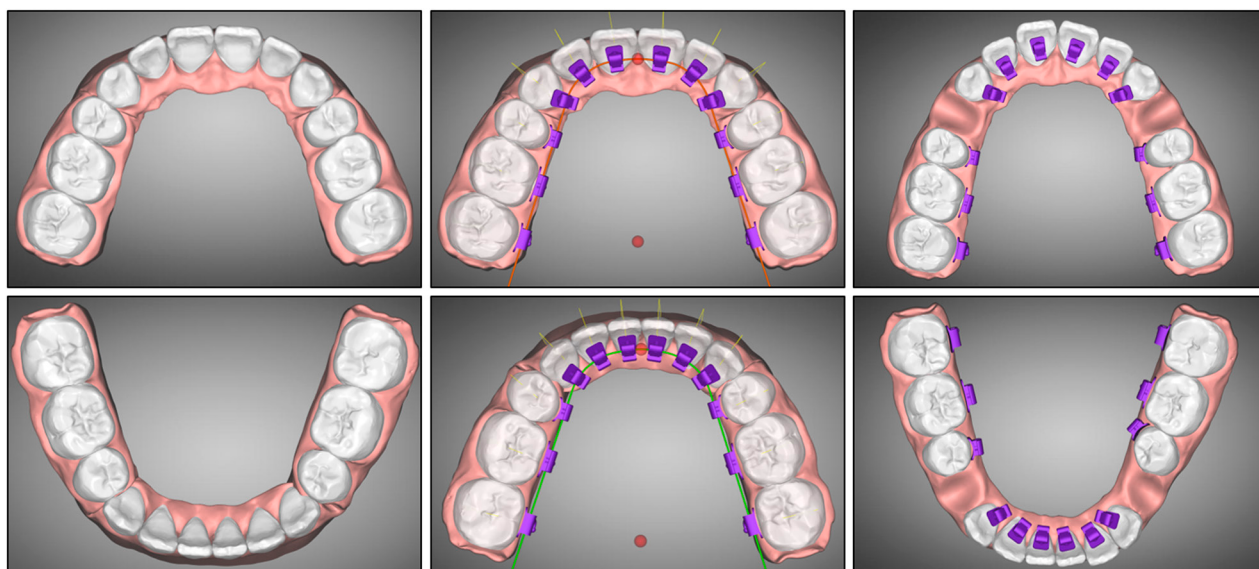


Figure 3. Digital orthodontic setup and bracket placement.

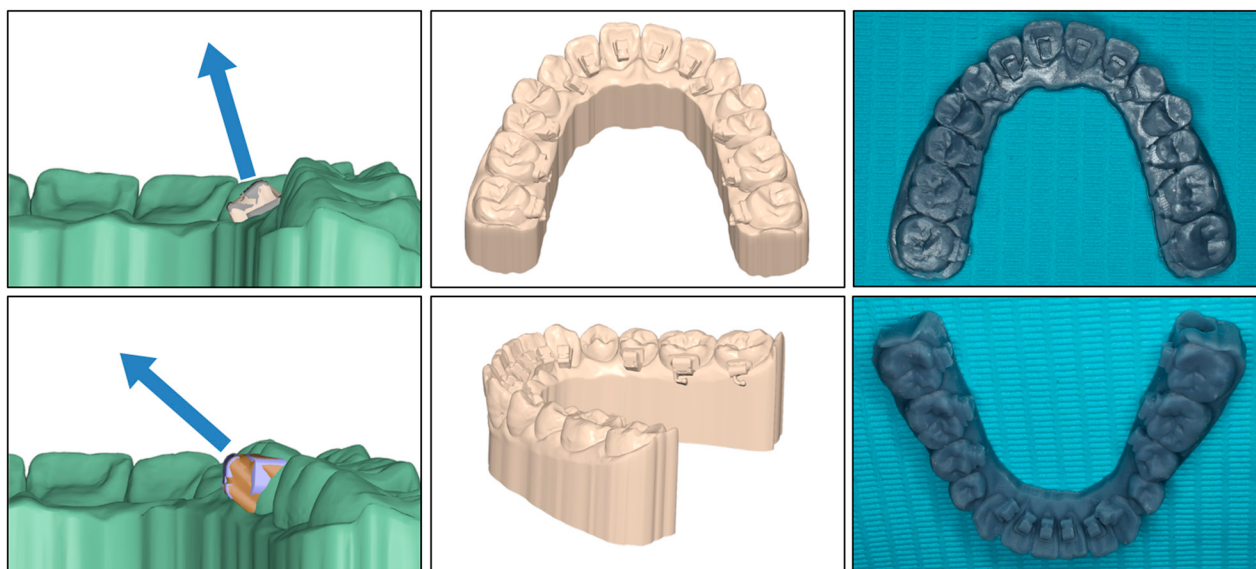


Figure 4. Virtual blocking out of bracket undercuts to facilitate rigid tray removal and 3D printing of models with ideal bracket positions.

adhesive was removed before light curing for 40 seconds. The rigid tray materials were reduced using pointed diamond burs (CD-53F, Mani, Germany) to facilitate tray removal and minimise bracket failure. Finally, intraoral scans were performed to assess the transfer accuracy by superimposing the post-bonded scans onto the virtual models which incorporated ideal bracket positions. The deviations between the bonded and planned bracket positions were measured in linear (mesiodistal, buccolingual, occlusogingival) and angular dimensions (rotation,

tip and torque) (Table II).³ One-sided t-tests were performed to determine if the bracket deviations were significantly below the clinically acceptable limits of 0.5 mm for linear measurements and 2° for angular measurements.

Treatment progress

The levelling and alignment stage was performed by engaging 0.014", 0.016", and 0.016" × 0.022" nickel-titanium arch wires. Six months later, the

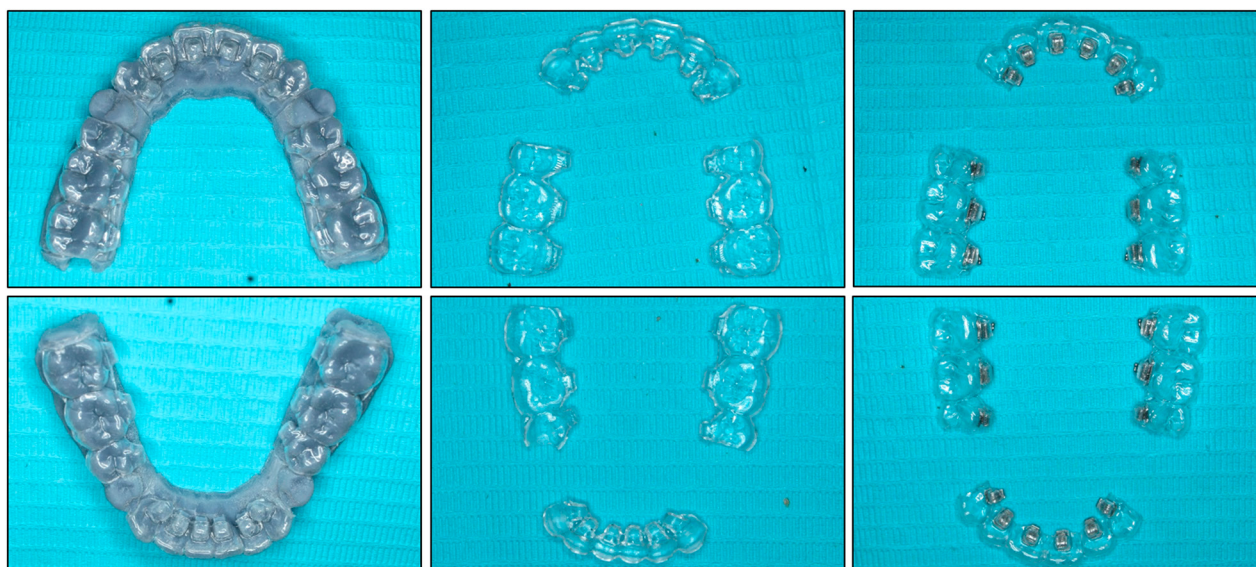


Figure 5. Fabrication of single rigid vacuum-formed indirect bonding trays and insertion of lingual brackets.

Table II. Deviations between bonded and planned bracket positions

Tooth type	Linear dimension			Angular dimension		
	MD (mm)	BL (mm)	OG (mm)	Rotation (°)	Tip (°)	Torque (°)
Incisor	0.055	0.047	0.050	1.252	1.350	1.907
Upper	0.036	0.028	0.051	1.113	2.052	2.248
Lower	0.074	0.066	0.049	1.390	0.649	1.567
Canine	0.057	0.022	0.048	0.689	1.817	0.829
Upper	0.061	0.021	0.051	0.659	1.669	0.621
Lower	0.052	0.023	0.046	0.720	1.966	1.036
Premolar	0.064	0.054	0.086	1.075	0.993	1.157
Upper	0.087	0.073	0.133	1.482	1.182	1.597
Lower	0.041	0.034	0.038	0.669	0.804	0.717
Molar	0.040	0.051	0.087	0.542	0.922	2.386
Upper	0.028	0.031	0.112	0.559	0.816	1.798
Lower	0.051	0.070	0.062	0.525	1.028	2.974
Total	0.052*	0.045*	0.068*	0.892*	1.226*	1.762

*Bracket deviations are significantly within the thresholds of 0.5 mm and 2°, as determined by one-sided t-tests.

BL, buccolingual; MD, mesiodistal; OG, occlusogingival.

upper and lower first premolars were extracted. The space closure stage was initiated by inserting 15° pre-torqued 0.016" × 0.022" stainless steel arch wires in both arches. Continuous power chains were applied to produce traction forces of approximately 150 g on each side. Additionally, two mini-screws of 1.6-

mm diameter and 8-mm in length (Hi-fix, Medico, Korea) were inserted into the palatal alveolar bone between the upper second premolars and first molars to reinforce upper posterior anchorage.¹⁰

After 10 months of traction, the extraction spaces were almost closed. However, the upper and lower

**Figure 6.** Intraoral photographs at the nineteenth month.

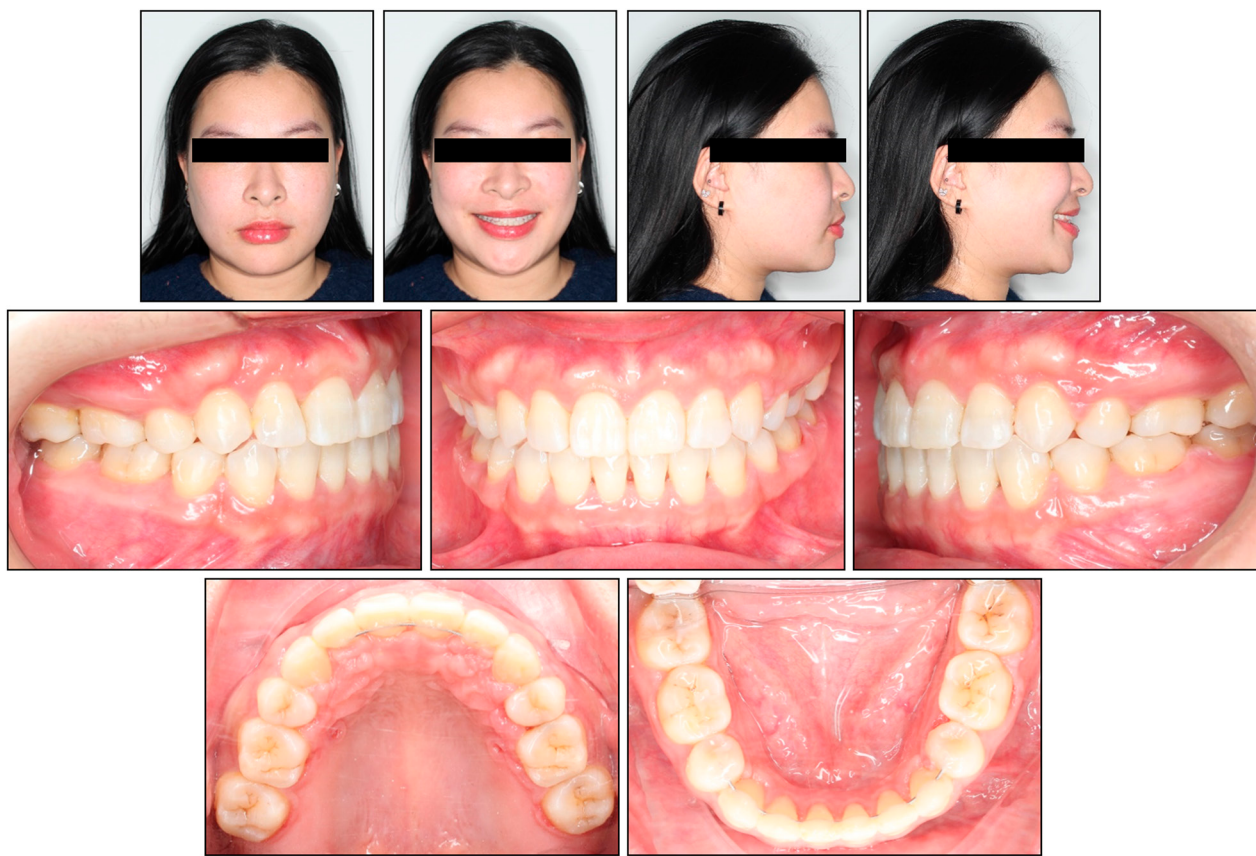


Figure 7. Post-treatment extraoral and intraoral photographs.

incisors exhibited lingual tipping. Hence, 20° pre-torqued 0.017" × 0.025" stainless steel arch wires were engaged in both arches to further increase the incisor torque. Additional buccal tubes were bonded on the molars to improve alignment by applying the cross-over technique (Figure 6).¹¹ The space closure stage took 16 months.

Minor wire bending was performed to correct several first-order malalignments during the finishing stage, which took another four months. During the entire treatment, three bracket failures occurred, involving the upper second molars and the lower left second premolar. The brackets were rebonded using individual transfer jigs fabricated by sectioning the rigid vacuum-formed indirect bonding trays. The total active treatment time was 26 months. After appliance removal, fixed retainers were placed in both arches.

Treatment results

Post-treatment extraoral and intraoral photographs showed that the patient's chief complaint was

addressed. The lip and dentoalveolar protrusion was significantly reduced, achieving a passive lip seal and a balanced profile (Figure 7). Class I canine and molar relationships were well maintained along with a normal overjet and overbite. The lower dental midline was aligned with the upper dental and facial midlines. The minor crowding in the lower arch was relieved.

On post-treatment lateral cephalometric evaluation, the anteroposterior and vertical jaw relationships showed no significant changes (ANB: 2.6°, FMA: 25.7°). The torque control of the upper and lower incisors was adequate as incisor inclination was in the normal range (U1-SN: 100.4°, L1-MP: 89.0°). Lip projections were significantly improved (upper lip/E-line: -0.8, lower lip/E-line: 0.8). The post-treatment panoramic radiographs showed acceptable root parallelism without signs of root resorption nor alveolar bone loss (Figure 8).

Cephalometric superimpositions showed the mesialisation of the upper and lower molars and

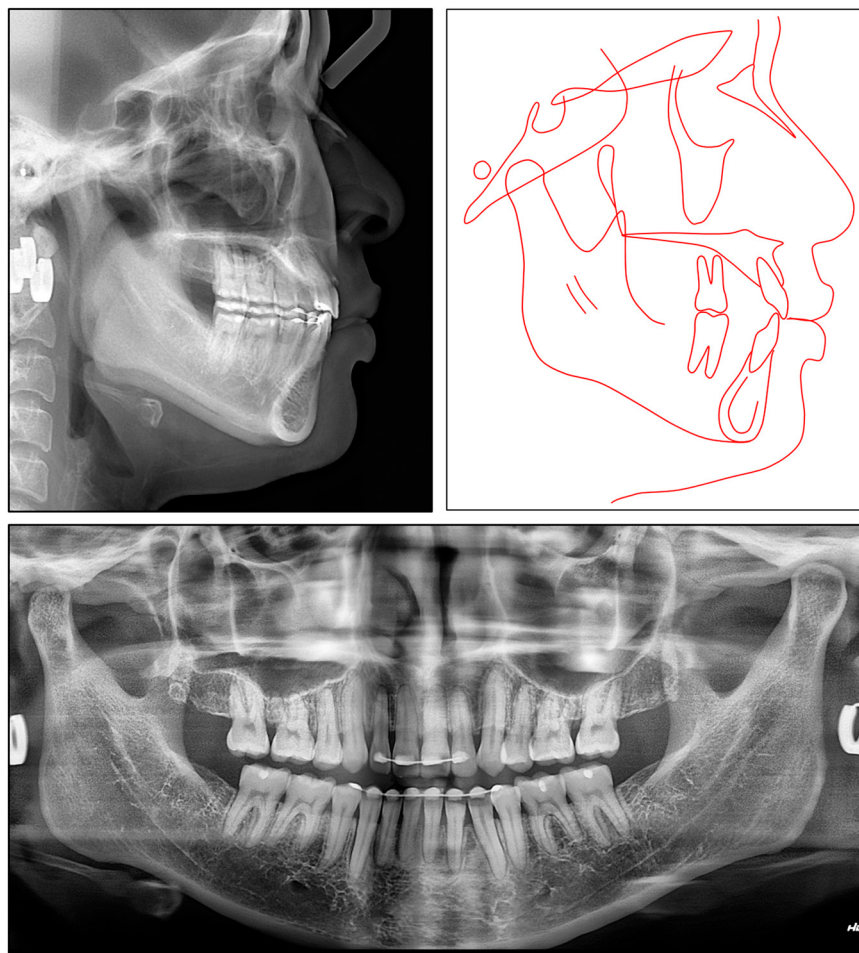


Figure 8. Post-treatment panoramic and cephalometric radiographs and tracing graphs.

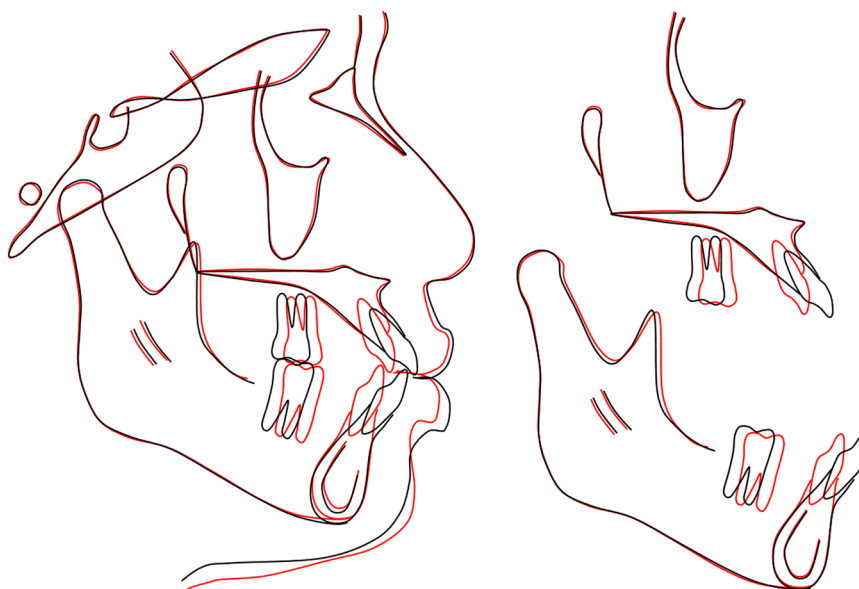


Figure 9. General and regional lateral cephalometric superimpositions: black, pre-treatment; red, post-treatment.

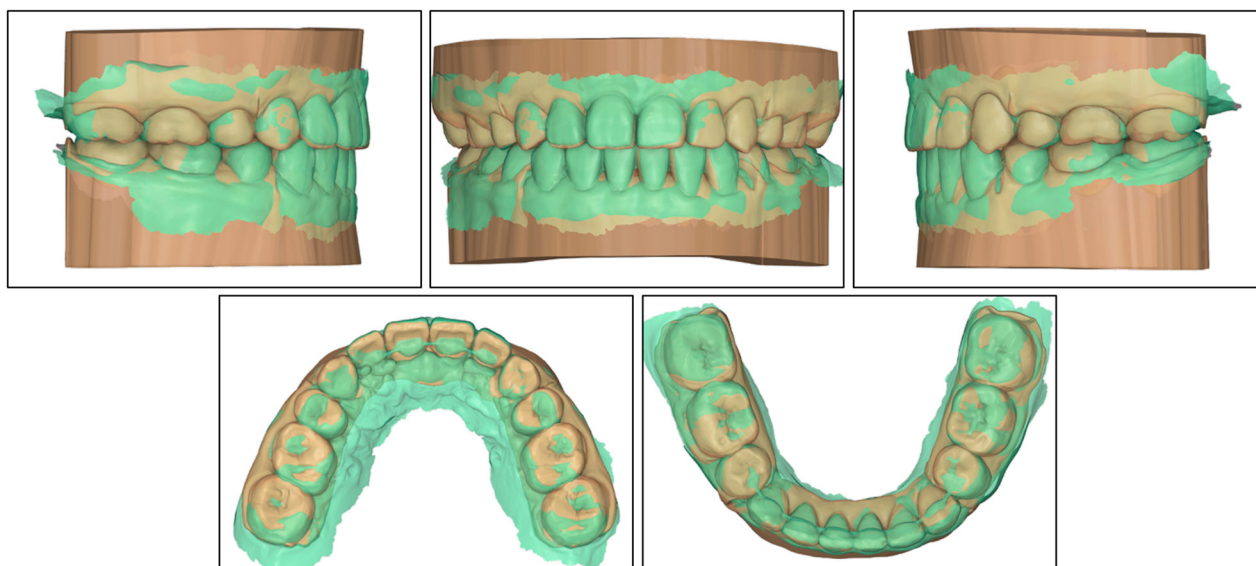


Figure 10. Superimpositions of the post-treatment intraoral scans (green) with the orthodontic setup models (yellow).

the controlled tipping of the upper and lower incisors (Figure 9). Superimposition of the post-treatment intraoral digital impression with the digital orthodontic setup showed high agreement between the planned and achieved movements (Figure 10). The one-year post-retention records indicated that the treatment outcome was stable (Figure 11).

Discussion

The present article reports a novel approach to fabricating individual, rigid, vacuum-formed, indirect bonding trays for lingual bracket application in a premolar extraction case. The transfer accuracy was high with average linear, rotation, and tip deviations within the clinically acceptable thresholds of 0.5 mm and 2°, respectively.⁷ However, torque deviations were not statistically below the acceptable limit although the deviation values are comparable with previous studies on double vacuum-formed and 3D-printed trays.^{3,7} Consistent with previous research, angular transfer accuracy was generally lower than linear accuracy, suggesting a common disadvantage across indirect bonding tray types. Additionally, the high agreement between the treatment results and the planned orthodontic setup indicated the high reliability of the digitally planned lingual orthodontic treatment.

When using the double vacuum-formed indirect bonding tray method, inner soft tray layers hold the

brackets by fully enclosing them and filling their undercuts. The flexibility of this layer allows tray removal after light-curing the attachment adhesives. The role of the outer hard layer is to maintain the form of the soft layer during tray placement. The idea of eliminating the inner soft layer became possible after the author's laboratory trials. A single hard tray layer can securely hold brackets in position without the need for a full undercut enclosure due to the tray's high elastic modulus. A fully enclosed design is not necessary with single rigid trays and may pose more difficulties during tray removal.

The present single rigid vacuum-formed indirect bonding trays offer several advantages over double vacuum-formed trays. Firstly, single-layer trays are more economical on material without the need for additional soft tray foils. Secondly, a partially enclosed tray design makes it easier to remove excessive adhesive. Furthermore, rigid trays are possibly more passive due to their rigidity. Therefore, actual bracket positions may be less dependent on finger pressure compared to soft trays, including flexible silicone and 3D-printed trays.^{7,12,13} This advantage is beneficial when individual brackets require rebonding during treatment, a situation in which double vacuum-formed trays are generally unreliable.⁴ However, rigid trays are more difficult to remove after adhesive curing, especially in crowded cases, because fewer insertion pathways exist. Hence, pointed burs are



Figure 11. One-year post-retention extraoral and intraoral photographs.

generally needed to grind tray material around the brackets which increases chairside time.

Unlike other rigid individual resin transfer jigs, the present vacuum-formed indirect bonding trays enable the placement of multiple brackets simultaneously, therefore potentially improving accuracy and saving time.^{1,2,5} It is more challenging to correctly position individual transfer jigs on small teeth such as lower incisors due to the lack of anatomical detail, and the possibility of transfer errors. Tray removal is also easier with vacuum-formed trays compared to rigid composite resin transfer jigs as the tray material does not bond to brackets.¹ Additionally, the present single vacuum-formed trays are simpler to design and fabricate compared to direct 3D-printed trays. However, this technique requires an intermediate step of printing 3D resin models, leading to more plastic waste in comparison with direct 3D-printed trays.^{7,12–14} Further comparative studies are required to assess the transfer accuracy of the present single rigid vacuum-formed trays against other indirect bonding tray types, such as double-vacuum formed, silicone, and 3D-printed trays.

Conclusions

The modified rigid single vacuum-formed tray technique offers a simple and cost-effective approach to lingual bracket indirect bonding. The agreement between planned and actual bracket positions, along with the close alignment between planned and achieved treatment outcomes, indicates the high accuracy and reliability of the technique. Further clinical studies with larger sample sizes are necessary to confirm the effectiveness and efficacy of this indirect bonding tray method.

Conflict of interest

The author declares that there is no conflict of interest.

Ethical statement

Informed consents were acquired from the patient and the parent both of whom agreed to the publishing of all images and clinical data included in the manuscript.

Corresponding author

Anh Viet Nguyen, Faculty of Dentistry, PHENIKAA University, Yen Nghia, Ha Dong, Hanoi 12116, Vietnam. Email: anh.nguyenviet1@phenikaa-uni.edu.vn

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