CASE REPORT

In-House 3D-Printed Shape Memory Aligners for Retreatment after Fixed Retainer Failure

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Recent advances in materials science[1] and computer-aided design and manufacturing (CAD/CAM) technology,[2] in combination with the growing number of adult patients seeking inconspicuous orthodontic treatment,[3] have led to the widespread adoption of clear aligners as a comprehensive alternative to fixed appliances.[4] Increasingly, the digital design and fabrication of clear aligners are occurring "in-house"—within a private practice.[5] The introduction of the first resin specifically intended for clear aligners[6] now allows trays to be 3D-printed with greater dimensional precision than thermoformed aligners,[7] while incorporating features such as planned variations in thickness across the aligner body and thermomechanical shape memory.[6,8,9]

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Fig. 1 32-year-old female patient with severe protrusion of lower left central incisor, lateral incisor, and canine due to failure of fixed lingual retainer, before retreatment.

KRAVITZ KEYS

- In this case report, a patient was retreated with three-dimensionally printed aligners produced in-house from a material with shape-memory properties.
- The aligners were manufactured from Graphy Tera Harz TC-85* photopolymer, using an Asiga Max UV** 3D printer and the Tera Harz Cure THC 2* polymerization device.
- Two identical aligners were delivered for each "step," involving .6mm of translation and as much as 4° of rotation.
- Each aligner was .6mm thick and was worn for one week.

To date, the literature on 3D-printed aligners largely consists of material[6,10,11] and in vitro studies,[9,12,13] with few investigations of their clinical efficacy. This article describes the digital design and in-house fabrication of customized aligners with shape memory to treat a case of failed fixed-wire retention, preventing the loss of a lower lateral incisor.

Diagnosis and Treatment Plan

A 32-year-old female who had previously undergone successful orthodontic treatment elsewhere presented to our practice with the chief complaint of a protrusive lower left canine (Fig. 1). Multistranded-wire lingual retainers had been bonded to the upper and lower incisors and canines. One year prior to our consultation, the retainer wire had come loose from the lower left canine, but it had been reattached before the patient noticed any changes in tooth position. The patient reported that within six months of rebonding, however, the lower left canine had moved significantly.

Clinical examination found a bilateral Class I occlusion with an open bite in the region of the lower left canine cusp, resulting in an asymmetrical lower arch due to the protrusion of the lower left incisors and proclination of the lower left canine. This proclination had caused the contours of the canine root to become visible on the lingual side. Gingival recession of 5mm, with no apparent inflammation, was noted on the buccal side of the lower left lateral incisor.

The panoramic radiograph confirmed the patient's overall dental and periodontal health. Cephalometric analysis (Table 1) indicated a skeletal Class II malocclusion due to a retrognathic mandible (SNB = 72.5°) and a vertical facial type (SN/Me-Go = 39°), along with retroclination of the maxillary base and a steep occlusal plane. The upper incisors were retroclined (U1-SN = 94°), and the lower incisors proclined (L1/Me-Go = 101°), while both were forwardly positioned (NPog-U1 = 18mm, NPog-L1 = 11mm), forming a convex lip profile.

The treatment goal was to restore the lower arch by retroclining the lower left canine and retruding the lower left incisors. Although our plan also addressed the gingival recession, only the orthodontic treatment will be detailed in this article.

The patient requested an invisible appliance, but fixed lingual appliances were ruled out because of the excessive orovestibular discrepancy between the lower left first premolar and canine. This discrepancy and the prominent undercuts, especially of the canine, eliminated conventional thermoformed aligners as a treatment option since removal of the trays from the molds would irreversibly deform them. To overcome these challenges, we planned to 3D-print customized aligners from a material with thermomechanical shape memory, thus enabling aligner insertion and removal while applying the continuous light forces needed to avoid exacerbation of the gingival recession.[12]

Treatment Progress

Digital planning was performed with Orthosetup*** software using a staging protocol with .6mm of translation and as much as 4° of rotational

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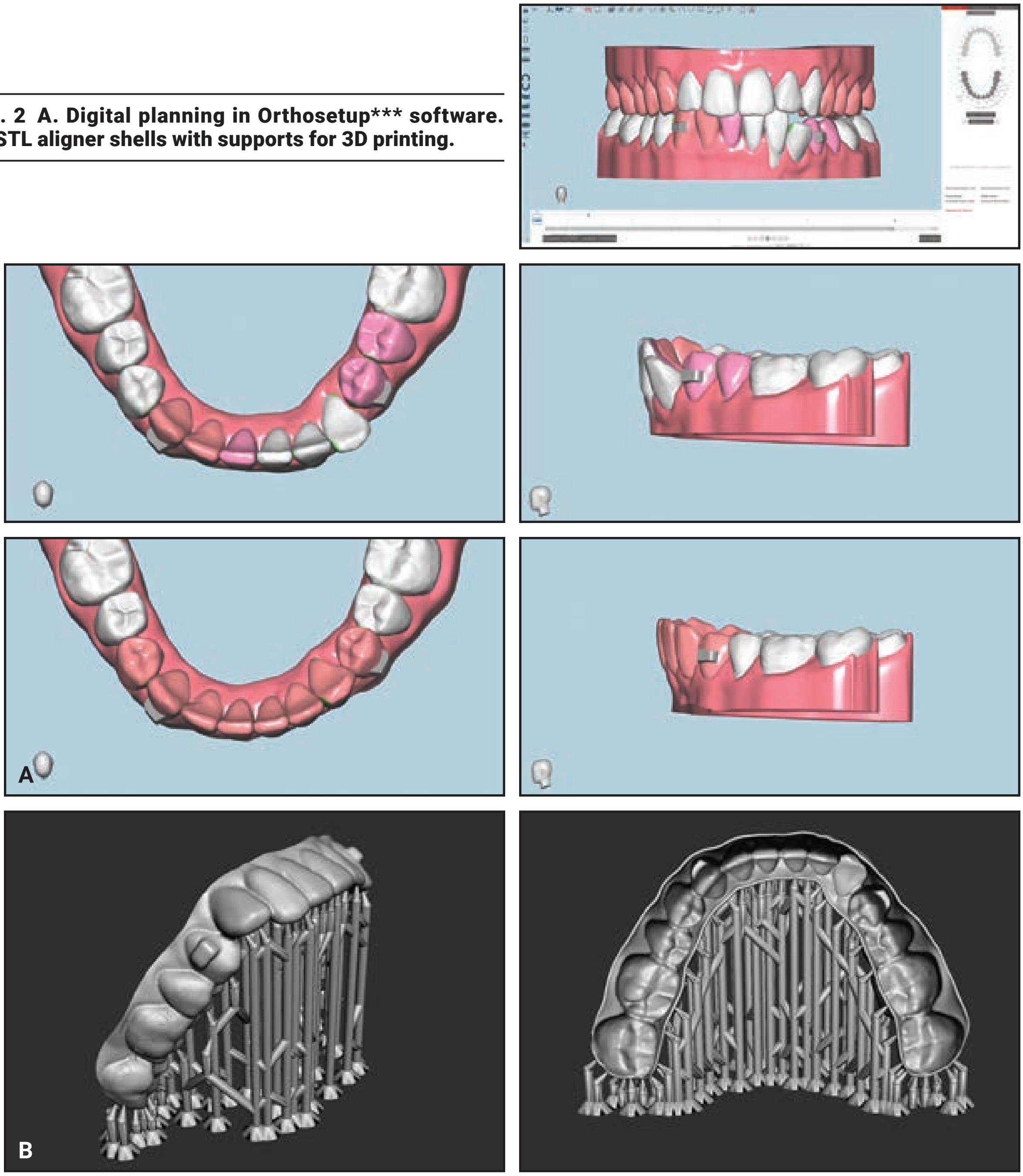
Fig. 2 A. Digital planning in Orthosetup* software. B. STL aligner shells with supports for 3D printing.**



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movement per step (Fig. 2). Nine steps were planned for alignment of the lower anterior teeth; two identical aligners were printed for each step, allowing the trays to be changed weekly and thus limiting any potential force-related consequences of deterioration. Passive attachments were planned for the central buccal aspects of the lower left first premolar and right canine.

The aligners were printed at a thickness of .6mm from Tera Harz TC-85 photopolymer, using an Asiga Max UV 3D printer and the Tera Harz Cure THC 2 polymerization device. A total of .4mm of interproximal reduction was performed on the mesial and distal sides of the lower left premolars to provide sufficient space for the intended incisor and canine movements.

Treatment progress was monitored every four weeks, with new aligners fabricated in time for each appointment. The patient reported that the aligners were more comfortable than the fixed orthodontic appliance that had been used during her previous treatment.

After the first nine steps had aligned the lower left canine and incisors (Fig. 3), six more aligners were produced for an additional three steps of refinement. Active treatment thus involved 12 steps, with a total of 24 lower aligners worn for 24 weeks (Fig. 4). A removable retainer was delivered for two months of wear, after which a lower 3-3 Nitinol CAD/CAM Memotain† lingual retainer wire was bonded (Fig. 5).

Treatment Results

The protrusion of the lower left incisors and proclination of the lower left canine were corrected, realigning the lower arch and closing the open bite. Controlled lingual tipping of the lower left

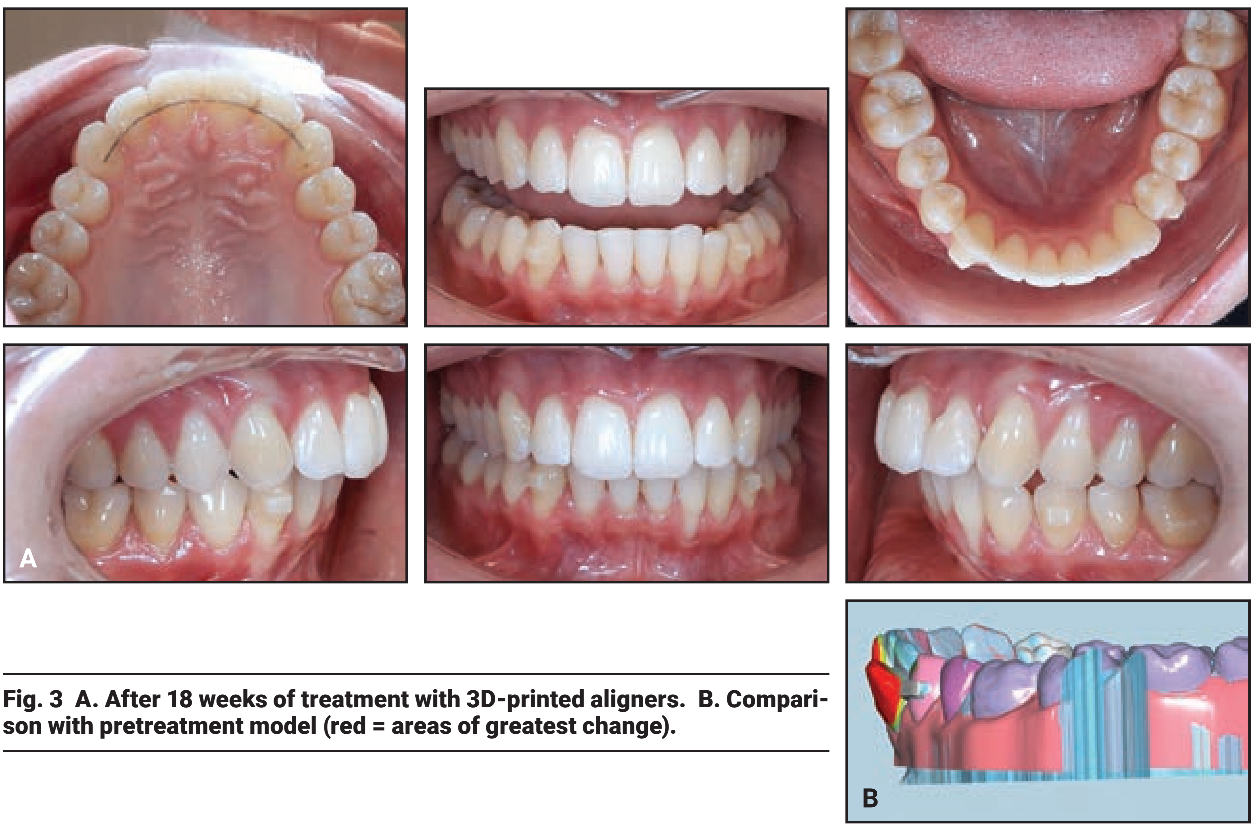

Fig. 3 A. After 18 weeks of treatment with 3D-printed aligners. B. Comparison with pretreatment model (red = areas of greatest change).

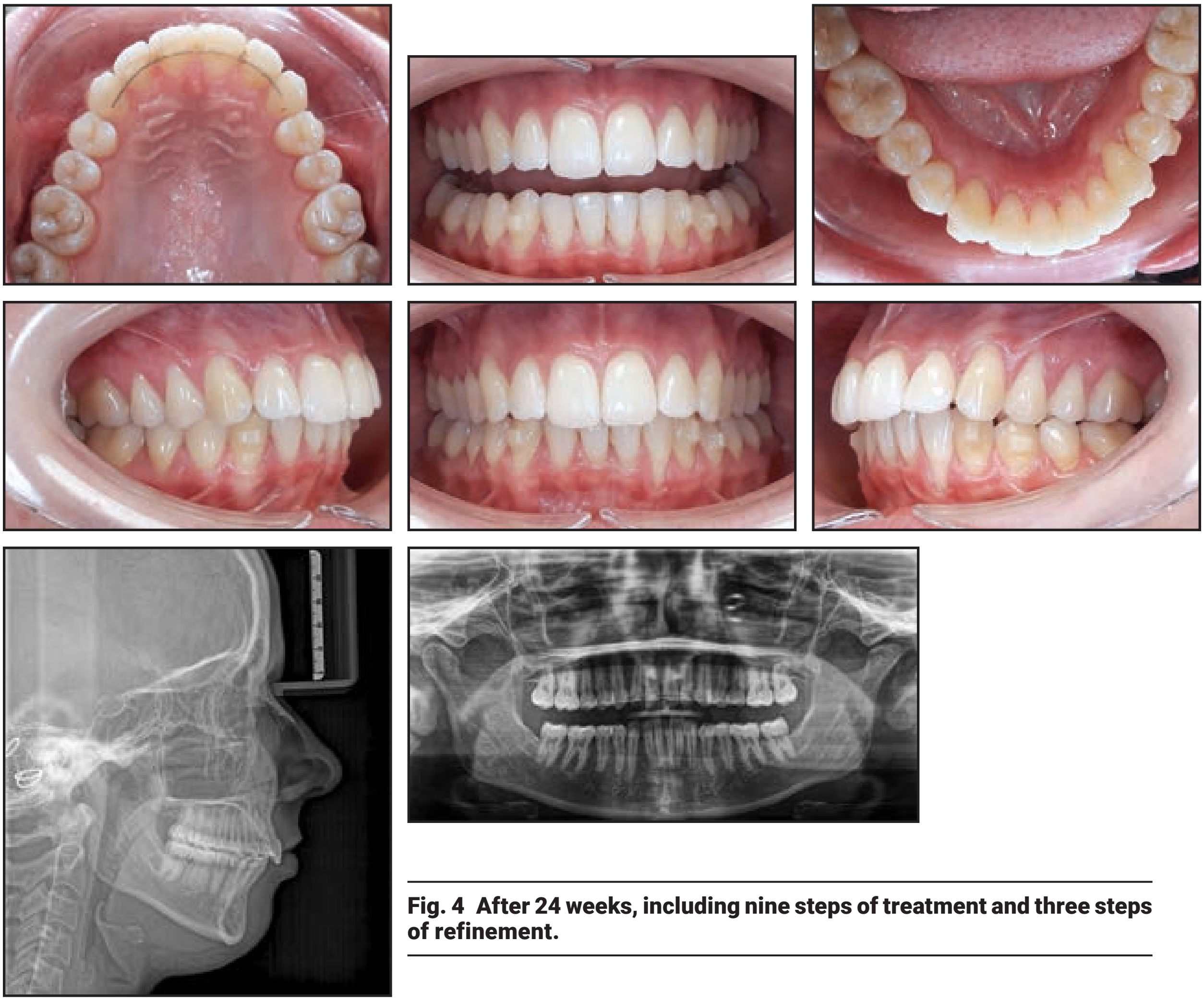

Fig. 4 After 24 weeks, including nine steps of treatment and three steps of refinement.

lateral incisor reduced the depth of the gingival recession from 5mm to 3.5mm and significantly decreased its width. No complications were noted, and the patient was satisfied with the esthetic results. Cephalometric analysis revealed no clinically significant sagittal or vertical changes (Table 1).

Discussion

This article documents the treatment of inadvertent tooth movement caused by the failure of a fixed lingual retainer wire. In contrast to a relapse—a return to the malocclusion corrected by orthodontic treatment—the failed retainer created an even worse malocclusion. The unanticipated torque tension induced by the wire severely compromised the health of the affected teeth. The lower left incisors and canine were affected primarily by the outward rotational force of the retainer wire. For the canine, this force resulted in uncontrolled tipping, which tilted the crown buccally and the root lingually (Fig. 1). When the left end of the wire moved in a buccal direction, it drew the crowns of the lower incisors buccally, while the

TABLE 1
CEPHALOMETRIC ANALYSIS

	Norm	Pretreatment		Post-Treatment	
SNA	81° ± 3°	79.0°	(→ orthognathic)	79.0°	(→ orthognathic)
SNB	79° ± 3°	72.5°	(→ retrognathic)	72.5°	(→ retrognathic)
ANB	2° ± 2°	6.5°	(→ skeletal Class II)	6.5°	(→ skeletal Class II)
Wits appraisal	♀: 0mm	+3.5mm	(→ skeletal Class II)	+4.5mm	(→ skeletal Class II)
NSGn (*y*-axis)	66° ± 3°	75.0°	(→ vertical)	75.0°	(→ vertical)
SN/Me-Go	32° ± 6°	39.0°	(→ vertical)	39.0°	(→ vertical)
SN/ANS-PNS	7° ± 3°	11.0°	(→ retroclined)	10.5°	(→ retroclined)
ANS-PNS/OcP	11° ± 2°	12.5°	(→ normal)	12.5°	(→ normal)
ANS-PNS/Me-Go	25° ± 3°	27.0°	(→ neutral)	27.5°	(→ neutral)
U1-SN	102° ± 2°	94.0°	(→ retroclined)	94.0°	(→ retroclined)
L1/Me-Go	90° ± 3°	101.0°	(→ proclined)	100.5°	(→ proclined)
NPog-U1	± 3mm	18.0mm	(→ forward)	18.5mm	(→ forward)
NPog-L1	± 0mm	11.0mm	(→ forward)	11.0mm	(→ forward)
Interincisal angle	135° ± 9°	127.0°	(→ normal)	125.5°	(→ smaller)

lingual root torque applied by the retainer kept their apices in about the same location. By tilting the root of the lateral incisor out of the alveolar bone, this movement promoted the development of gingival recession.

When the gingival tissue around a tooth is damaged, it is imperative to apply targeted, consistent forces of low magnitude for traction.[12] Unlike standard thermoformed aligners, those printed with TC-85 photopolymer have been shown to adapt fully to the shapes of the incisor crowns,[10] enabling targeted application of the necessary light forces.

Our plan also took advantage of the TC-85 material's shape-memory feature, which enables an aligner to become flexible enough for easy insertion when exposed to hot water but to return to its original shape upon cooling to body temperature. That flexibility also makes the aligners more comfortable to wear.[10]

Despite the many potential advantages of this new material, the relatively small body of literature regarding its clinical performance may have limited our treatment options. Our aligners were designed to be changed weekly because a study of the ability of 3D-printed TC-85 aligners to maintain their mechanical properties during use tested them for only one week.[14] Although the TC-85 resin allows different parts of the aligner to be printed at different thicknesses,[9,15] potentially producing force vectors comparable to those achieved with attachments on the teeth,[13] we relied on conventional attachments because no evidence-based scientific study had measured those forces in a case similar to ours. Further gaps in the literature include the consequences of errors made during certain steps in the workflow for designing and printing aligners, which can sometimes result in substantial unintended forces and moments.[13,16]

This case underscores the efficacy of customized, technologically driven approaches in

Fig. 5 About eight months after beginning of treatment, with bonded lower 3-3 Memotain† lingual retainer wire in place.

treating complex cases. The unique properties of 3D-printed aligners with shape memory allowed us to save a lower lateral incisor with an impaired periodontium and effectively manage protruded lower incisors and a proclined lower canine without the need for additional skeletal anchorage. As the body of scientific and clinical knowledge about 3D-printed aligners continues to grow, they are likely to become a transformative alternative to standard thermoformed aligners and conventional fixed appliances.

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