Guidelines for a surgery-first approach using Dolphin Imaging software and the Invisalign system

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Recent technological innovations allow for the integration of clear aligner therapy (CAT) with orthognathic surgical procedures, making the surgery-first orthognathic approach a reality. Combining CAT with this surgery-first strategy offers a compelling solution for both patients and orthodontists seeking a faster and less visible treatment. Although the combination of CAT and surgery-first orthognathic approach presents potential advantages for practitioners in orthognathic surgery, it also introduces new challenges. A significant obstacle is the effective transfer of the virtual surgical planned occlusion and jaw relations into the aligner software to allow for aligner manufacturing before surgery. To date, no protocol has described effective transfers of the virtual surgical plan to the CAT software. This article presents a novel method for this transfer, using the freely available software (Meshmixer, version 3.5; Autodesk, Armonk, NY) in 2 patient scenarios. (Am J Orthod Dentofacial Orthop Clin Companion 2024;4:182-7)

The integration of a surgery-first orthognathic approach (SFOA) with clear aligner therapy (CAT) offers a treatment modality for adult patients seeking an esthetic,[1] more comfortable,[2,3] and hygienic solution to their skeletal malocclusion. To maximize the benefits of regional and systemic acceleratory phenomenon,[4,5] aligner planning and manufacturing before SFOA is essential. Notably, there is a lack of comprehensive guidelines and protocols addressing the integration of virtual surgical planning (VSP) in aligner software,[6] particularly when considering complex orthognathic procedures such as the 3-piece segmental maxillary osteotomy.

The VSP is conducted using the Dolphin Imaging software (version 11.9; Dolphin Imaging and Management Solutions, Chatsworth, Calif), followed by postsurgical orthodontic treatment using the Invisalign system (Align Technology, San Jose, Calif). The presurgical intraoral scan is digitally aligned to the presurgical cone-beam computerized tomography, and jaws are aligned in compliance with the surgical plan and into the best-fit occlusion.

Consequently, the objective of this article is to propose a CAT-SFOA digital workflow, exemplified by two patient scenarios, necessitating a total Le Fort I and a segmental Le Fort I osteotomy, respectively. This research contributes to the limited existing literature on digital workflows for the CAT-SFOA, including a segmental maxillary osteotomy paired with aligner treatment. Moreover, it presents a comprehensive guide offering clinicians an additional layer of potential digital workflows within the domain of CAT-SFOA.

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The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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STEP-BY-STEP WORKFLOW USING DOLPHIN IMAGING SOFTWARE AND THE INVISALIGN SYSTEM

1. An intraoral scan was taken and uploaded to ClinCheck (Align Technology, San Jose, Calif) to plan conventional attachments because of postsurgical restricted mouth opening capacity. Four sets of passive aligners were requested for changes on a weekly basis leading up to the surgery.
2. To start the VSP, an initial clinical examination, a construction bite, ideally with the temporomandibular condyles in centric relation, complemented by a cone-beam computerized tomography followed by an additional intraoral scan with the attachments,[7] was conducted (Fig 1).
3. VSP was completed in Dolphin Imaging software. The planned occlusion with the maxillary and mandibular arch is then exported as a stereolithography (STL) file, illustrated in Figure 2.
4. Because the Invisalign system is not accepting the STL files presenting the exported planned occlusion from Dolphin Imaging, Meshmixer (version 3.5; Autodesk, Armonk, NY) was used to align the presurgical scan to the postsurgical occlusion created in Dolphin Imaging software (Fig 3).

   Regarding the total Le Fort I approach, the maxillary and mandibular model from the intraoral scan was repositioned manually in the postsurgical occlusion to roughly match the teeth of the planned occlusion. Next, all the visible surfaces of the teeth were marked and aligned to the planned occlusion. The entire procedure is documented (See Video 1, available at https://1drv.ms/f/s!AvFbshQnWfZigzX7YAt3wDlLoZ61?e=OskuSB).
5. Regarding the segmental Le Fort I osteotomy approach, the procedure differs from the total Le Fort I because the presurgical maxillary model must be digitally cut in Meshmixer between the lateral incisor and the canine in the maxilla, simulating the surgical cuts. The teeth of each segment were marked and aligned separately to the postsurgical planned occlusion from Dolphin. This procedure is also documented (See Video 2, available at https://1drv.ms/f/s!AvFbshQnWfZigzZYLijUjByRsMYi?e=yA6uIF).
6. Both modified model sets indicating the postsurgical occlusion for the total Le Fort I and the segmental Le Fort I osteotomy were printed out in resin, specifically used for printing orthodontic models. The iTero scanner (Align Technology) was used with the following steps (Fig 4): (1) by pressing the *AddRx* function, a duplicate scan of the patient's original scan was created; (2) the occlusion part of the scan was erased; (3) the models oriented in the planned postsurgical occlusion was scanned, and (4) iTero scanner

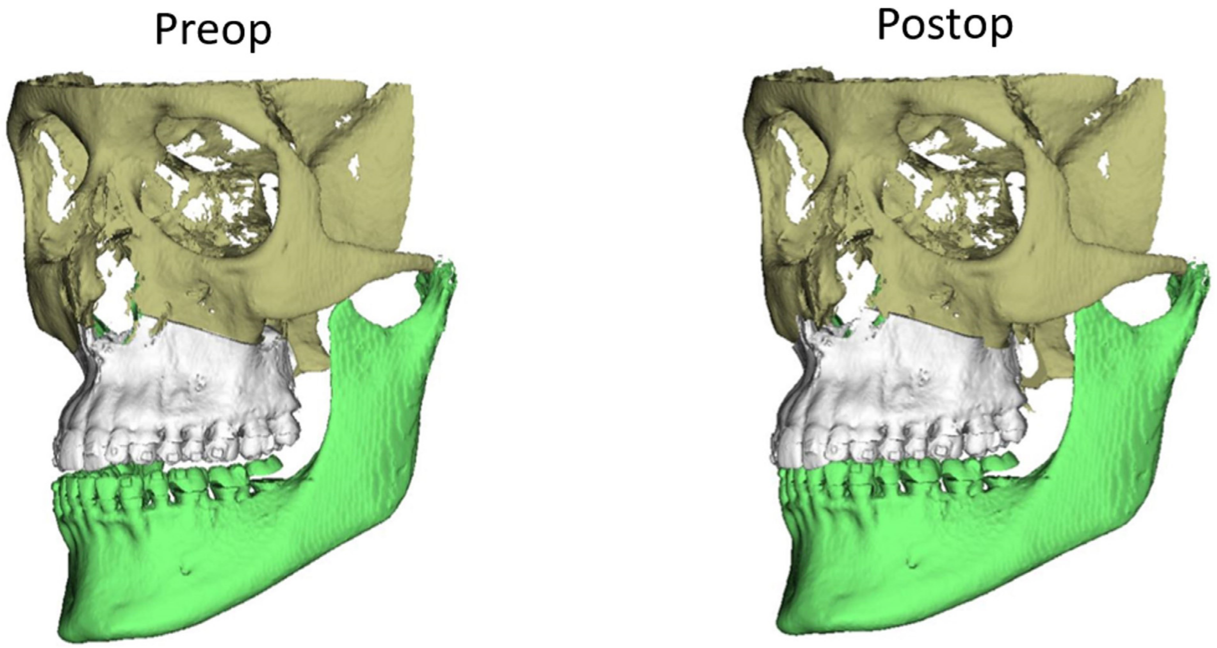

Fig 1. The presurgical and postsurgical outcome in Dolphin Imaging software (version 11.9; Dolphin Imaging and Management Solutions, Chatsworth, Calif) illustrates the initial malocclusion defined as preoperative and after the surgical simulation defined as postoperative. *Preop*, preoperative; *Postop*, postoperative.

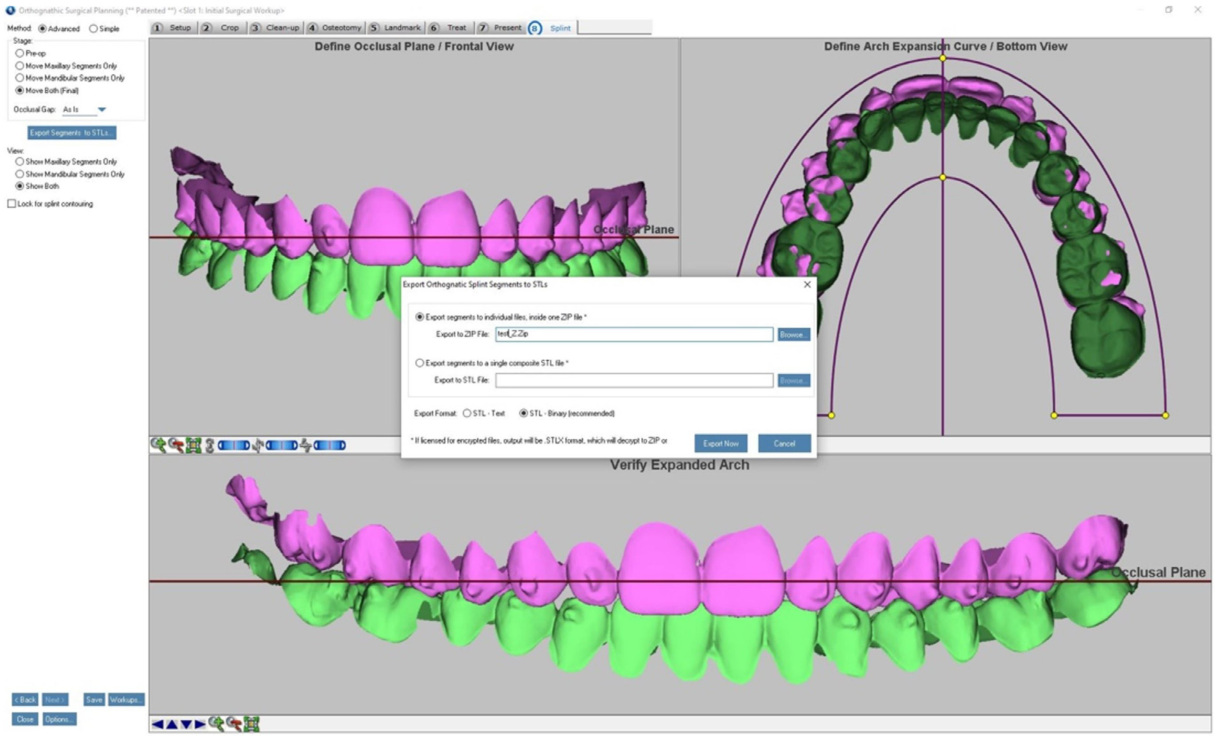

Fig 2. Exportation of the planned occlusion after digital planning of the Le Fort I osteotomy in Dolphin Imaging Software (version 11.9; Dolphin Imaging and Management Solutions, Chatsworth, Calif).

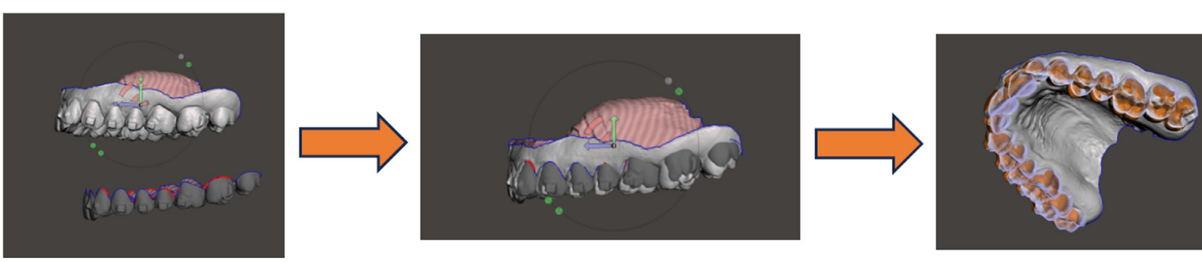

Fig 3. The alignment of the presurgical scan to the planned occlusion of the total Le Fort I osteotomy from Dolphin Imaging (version 11.9; Dolphin Imaging and Management Solutions, Chatsworth, Calif) within the Meshmixer (version 3.5; Autodesk, Armonk, NY) interface.

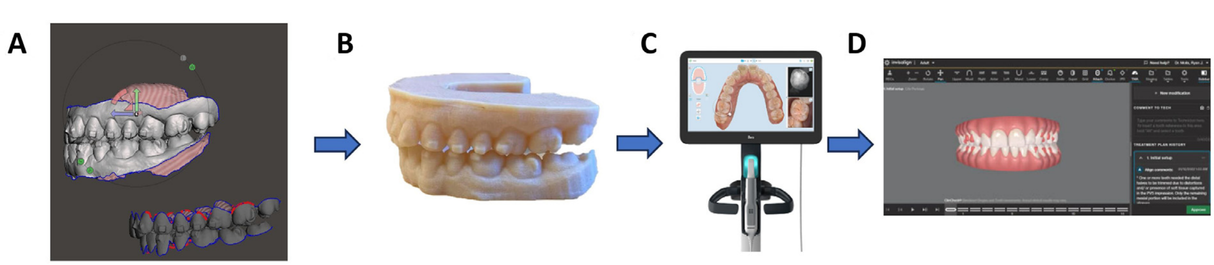

Fig 4. Total Le Fort I osteotomy: **A,** Meshmixer (version 3.5; Autodesk, Armonk, NY) alignment of presurgical arches matched to the planned occlusion from Dolphin Imaging (version 11.9; Dolphin Imaging and Management Solutions, Chatsworth, Calif) (steps 1 and 2); **B,** The printed model with attachments; **C,** The scan of the new occlusion within the scan of the patient's original scan; **D,** The implementation of the modified scan in the Invisalign system (Align Technology, San Jose, Calif).

automatically recognized the teeth and the planned postsurgical occlusion becomes a part of the duplicate scan.

7. The scan was submitted to Invisalign, and the ClinCheck was based on the planned postsurgical occlusion derived from Dolphin VSP for orthodontic postsurgical adjustments to the tooth position. No further instructions were given to the technicians regarding the occlusion.

Overall, steps 1-6 were conducted for both the total Le Fort I and for the segmental Le Fort I osteotomy, respectively.

The alignment of the surgically planned occlusion (Le Fort I and segmental Le Fort I) using Meshmixer (step 2) was performed 10 times by each of the two examiners (M.S. and S.V.) to determine the mean time use required for this stage.

Because of the higher challenges of the SFOA workflow involving a segmental Le Fort I osteotomy, a 1-week postoperative scan of the patient was acquired to identify potential deviations from the virtual surgical plan in relation to the actual surgical outcome. Consequently, the postsurgical planned occlusion and actual occlusion after surgery were superimposed using a point-to-point method in the open-source software MeshLab (ISTI-CNR, Pisa, Italy), selecting reference points at the third palatinal rugae. A precise superimposition was then realized through the iterative closest point algorithm, following the methodology adopted by Pozzan et al.[8] Each examiner assessed the Hausdorff distances between preoperative planned and postoperative models 10 times to evaluate variations between their measurements using a Wilcoxon signed rank test and the paired t-test. Furthermore, a 1-sample t-test was conducted separately for the two examiners to determine if the sample significantly deviated from 0. The statistical evaluations were executed using Python (version 3.11.5).

RESULTS

For the patient with the Le Fort I osteotomy, the mean time used for examiners 1 and 2 was 7.1 and 8.3 minutes, respectively. Because isolated maxillary adjustments retained the teeth in their original orientation, the aligners were assessed to fit after executing steps 1-6 as accurately as patients treated with aligners but not surgery.

The mean time executing the segmental Le Fort I osteotomy alignment procedure in Meshmixer was 16.2 and 19.4 minutes for examiners 1 and 2, respectively.

Comparing the planned postsurgical occlusion model with the actual postsurgical occlusion of the segmental maxillary osteotomy, each examiner calculated Hausdorff distances 10 times. The average Hausdorff distances recorded by examiners 1 and 2 were 0.69 mm and 0.71 mm, respectively, with both having a standard deviation of 0.05. Figure 5 displays the histogram of the calculated Hausdorff distances (minimum, 0.0 mm; maximum, 4.2 mm) between the presurgical and postsurgical models. More specifically, the histogram illustrates subtle discrepancies (0-1 mm) between the planned and actual models in the anterior segment. In contrast, the lateral segments exhibit variations between 1-3 mm on both the buccal and palatal sides of the canines within both lateral segments. In addition, the 1-sample *t test* calculated for each examiner using values from the Hausdorff sampling revealed that the calculated Hausdorff distances deviate from 0. There is a significant difference between the preoperative planned model and the actual postoperative model, as evaluated by both examiners.

From a clinical standpoint, the aligners fabricated following steps 1-6 were not fitting. Notably, they could not be accurately seated on the lateral segments. Consequently, a postsurgical scan for new aligners was necessary.

To compare the Hausdorff distances calculated from examiners 1 to 2, both tests yielded P values above the common significance threshold of 0.05 (P = 0.453 and 0.443, respectively). This suggests that there is no statistically significant difference in the measurements between the two examiners.

DISCUSSION

The integration of the surgery-first approach with aligner technology still presents challenges. The Invisalign system stance on not supporting external VSP software files, such as those from Dolphin Imaging, coupled with limitations on mandibular movement in ClinCheck, add to the complexities of this domain.

Using the workflow presented in this article, a satisfactory aligner fit was obtained in the total Le Fort I orthognathic surgery. More specifically, the manufactured aligners fitted and could be inserted during surgery. Attachments were placed before the VSP as described in step 2. This makes it possible for the patient to use the aligners early in the postoperative phase. The occlusion part of the scan was erased as described in step 5 to rescan the occlusion oriented in the planned surgical occlusion. Regarding the segmental Le Fort I, a postsurgical scan of the patient was necessary. The manufactured aligners did not fit because of a deviation of the virtual planned occlusion to the surgical outcome. After superimposing the presurgical planned maxillary model to the postsurgical actual model, deviations of 1-3 mm at the region of the canines on both lateral segments were calculated. However, these inaccuracies are not likely related to the workflow but to the discrepancy between the VSP and the surgical outcome. Regarding the segmental Le Fort I scenario, to keep the transverse dimension in the postsurgical orthodontic phase, a 3-dimensional (3D) printed transpalatal arch bonded on the maxillary first molars was placed intraoperatively and left in for 9 weeks in combination with the active aligners. The maxillary first

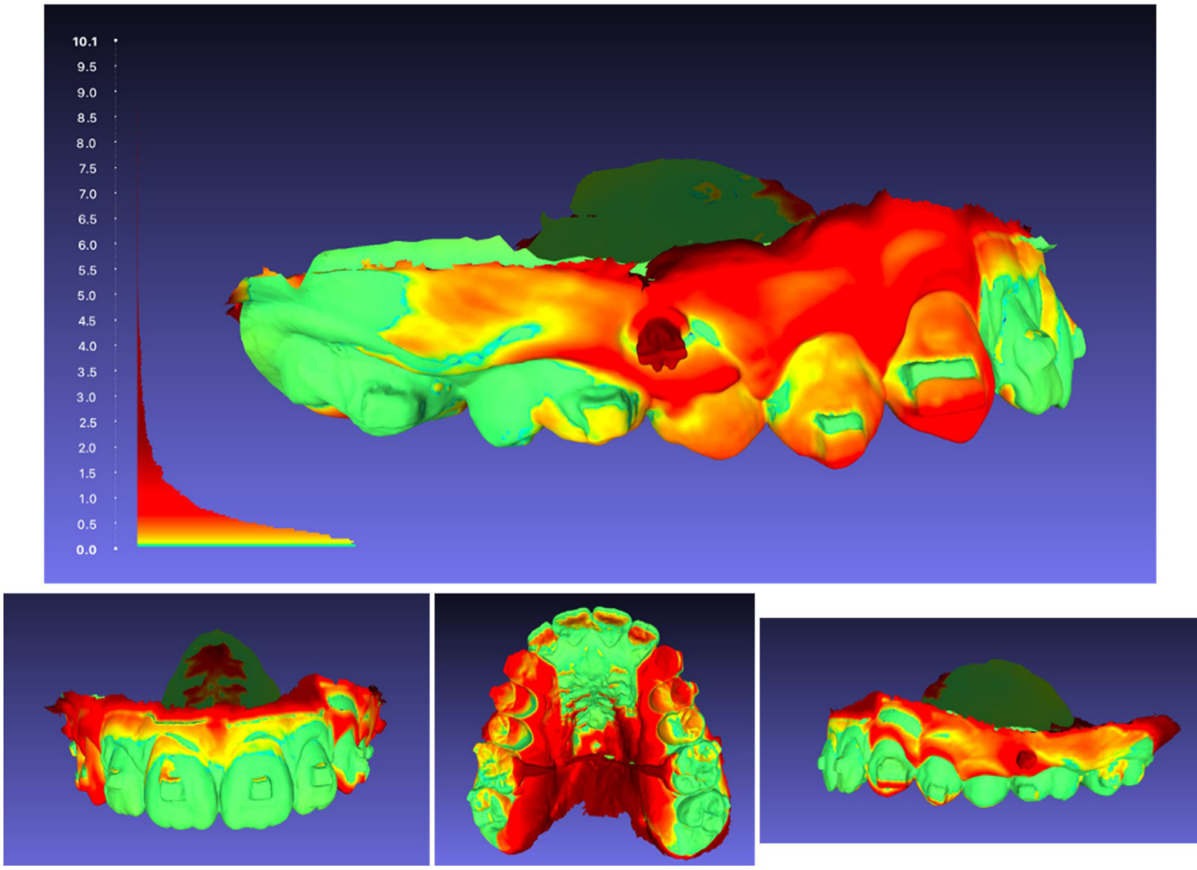

Fig 5. Histogram with the computed Hausdorff distances between the planned and postoperative models for the segmental Le Fort I osteotomy procedure. These distances span a range of 0.0-10.0 mm and are presented across the anterior, lateral, and occlusal perspectives. Planned occlusion is displayed in *green*, whereas the postoperative occlusion is marked in *red*.

molars were planned to be unmovable in the ClinCheck with palatal cutouts in the aligners to ensure proper fitting. The use of customized surgical guides could aid in minimizing discrepancies and enhancing aligner fit.[9-11] Moreover, superimposing at the palatal rugae after surgery might be compromised because of soft-tissue swelling.[12] Overall, the proposed workflow allowed the postsurgical insertion of the aligners in a patient with Le Fort I osteotomy without complications.

Only a few studies[6,13,14] have published protocols regarding aligners in conjunction with orthognathic surgery. Software, such as OrthoCAD (AlignTechnology, San Jose, Calif),[13] has been spotlighted for its functional utility in presurgical preparation. An alternative workflow involves replicating the surgical plan within the Invisalign system, aided by the company's technicians. In the surgery-first approach, when the postsurgical arch alignments might be unclear to aligner technicians because of missing decompensations, communicating the planned occlusion may be time-consuming, possibly inaccurate, and less efficient.

A potential limitation of this workflow might be the necessity to employ alternative software, such as Meshmixer. Nonetheless, as an open-source software, it does not impose financial burdens on clinicians. When applying this workflow for the Invisalign system, another potential drawback is the necessity of a 3D print of the models after VSP in the planned occlusion. If continuous liquid interface production or a digital light processing printer with a suitable setting is used, the accuracy of 3D printing and rescanning is acceptable.[15] However, in other aligner software, 3D printing of the models is unnecessary. One could export the STL files from Meshmixer oriented in the planned occlusion to the designated aligner software, thereby opening up the possibility of using this workflow for in-house aligner planning and manufacturing. Steps 1-6 could be easily delegated to staff. In addition, palate reconstruction can be challenging to predict, given the potential variability in postsurgical outcomes. However, a recent article indicated that patients using Invisalign experienced less facial swelling during the initial postoperative week than those with fixed devices.[16]

CONCLUSIONS

This method can reduce treatment duration because the surgery can be performed during or after the fabrication process of the aligner. This technique omits one intraoral postoperative scan and more effectively uses the duration period of the regional and acceleratory phenomenon, improving patient comfort and significantly reducing chair and treatment time.

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CONFLICTS OF INTEREST

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.

STATEMENT OF INFORMED CONSENT

Informed consent was obtained from the patient for the use of digital material and radiographs for publication.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.xaor.2024.03.006. (See Videos 1 and 2, available at www.ajodo.org).

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