Clear Aligner Orthognathic Splints

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Orthodontic treatment has been transformed by the introduction and overwhelming adoption of clear aligner therapy (CAT). Many patients are demanding esthetic and metal-free treatment alternatives, including those requiring orthognathic surgery (OGS), to correct their dentofacial deformities. The adoption of performing OGS for CAT has been cautious and challenging for many reasons. Intermaxillary fixation, postoperative occlusal control, preoperative decompensation management, and long-term stability need to be tested and assessed. This report presents an accurate 3-dimensional (3D) printed hard acrylic splint specifically for patients without any orthodontic attachment to be used in the positioning and fixation of osteotomized jaws. It is simple to manufacture and its use intraoperatively is efficient, straightforward, and accurate. This report introduces the Clear Aligner Orthognathic Splint for surgery and the steps required for 3D planning with recommendations for perioperative orthodontic support.

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Orthognathic surgery (OGS) has seen remarkable improvements in its planning and technique since its initial conception.[1] Advancements in digital technology have allowed the progression from 2-dimensional cephalometric radiographs to 3-dimensional virtual analysis and treatment planning using cone-beam computed tomography (CBCT).[2-5] The use of computer-aided design and computer-aided manufacturing (CAD/CAM) technology to fabricate splints for aiding intraoperative positioning of the osteotomized maxillofacial complex has been particularly impactful to oral and maxillofacial surgery.[4,6] These technologic innovations have affected not only oral and maxillofacial surgery but also orthodontics, especially with the development of clear aligner therapy (CAT).[7-10] Due to increased public demand for more esthetic and comfortable treatment options, currently there is a multitude of manufacturers available for CAT on the market.[11-14] Subsequently, more patients than ever have been seeking OGS in conjunction with CAT at the authors' center for corrective jaw surgery. This trend brings a new challenge to the oral and maxillofacial surgeon and the orthodontist, because knowledge in this field is currently limited.[15]

Although contemporary CAT has been available since the late 1990s, the technology was initially proposed only for treatment of mild malocclusions.[16] The adoption of CAT with OGS has been slow, because skeletal deformities and other severe dentoalveolar problems were initially listed as a contraindication by the Food and Drug Administration (FDA).[17] As the technology improved, CAT was gradually used for more complex cases, with the FDA ultimately changing these contraindications to precautions.[17] These improvements include better preoperative treatment planning setups,[8,18] digital planning using intraoral scanners and CT,[19] intraoperative techniques for fixation and positioning,[20] and presurgical orthodontic mechanical support, creating a more fluid transition for most orthognathic cases.

A major challenge of performing OGS with CAT is intraoperative control of the occlusion.[21] Although these protocols are well established in the literature

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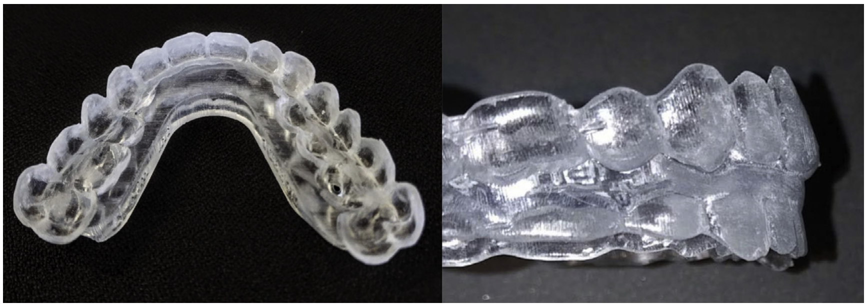

FIGURE 1. Occlusal and lateral views of the Clear Aligner Orthognathic Splint.

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FIGURE 2. Preoperative cone-beam computed tomograms of case 1, illustrating the maxillomandibular dentoalveolar discrepancy.

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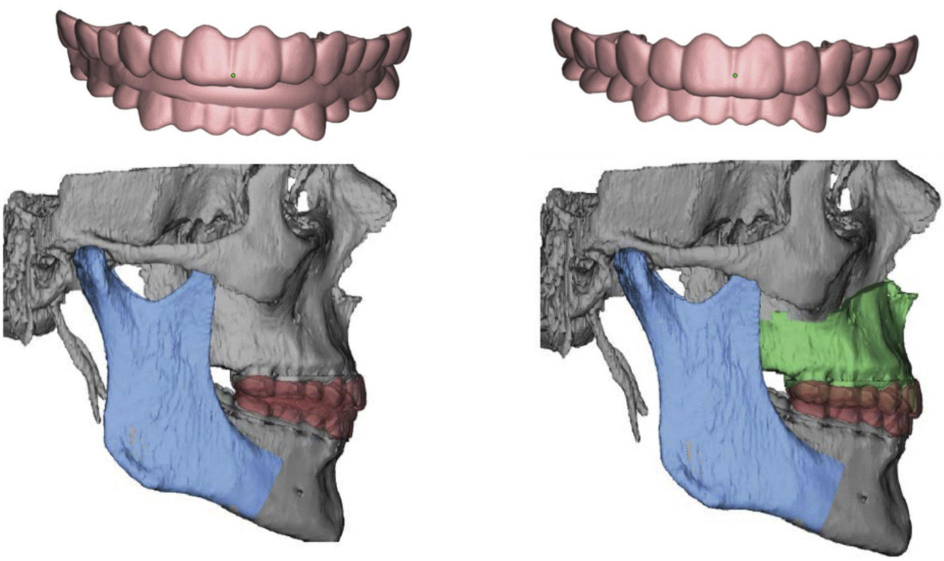

FIGURE 3. *Right*, Three-dimensional image of intermediate splint and its position in the virtual model. *Left*, Three-dimensional image of final splint and its position in the virtual model.

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FIGURE 4. Clinical photograph of the final splint used for guidance in rigid fixation of the maxilla.

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and readily performed for patients with fixed orthodontic appliances, they are not well elucidated for CAT cases.[22-24] To date, knowledge of CAT with OGS is minimal, with most being case reports.[25-30]

A recent article by Taub and Palermo[20] described a number of techniques for maxillomandibular repositioning and fixation in patients undergoing CAT, such as Erich arch bars, Ivy loops, and inter-jaw fixation (IMF) screws. This report presents a novel technique for achieving repositioning and fixation using the Clear Aligner Orthognathic Splint (CAOS), fabricated with the help of CAD/CAM technology (Fig 1). The goal of this report is to show the clinical usage of CAOS, describe the virtual manufacturing process, and present potential advantages, limitations, and recommendations for perioperative orthodontic care.

Materials and Methods

CASE 1

This case shows the use of the CAOS in bimaxillary CAT-treated arches. The patient has a Class III malocclusion (Fig 2) requiring a Le Fort I advancement and a bilateral sagittal split osteotomy (BSSO) setback for the correction. The preferred method at the authors' center is the mandible-first approach, because it eliminates the need for a 2-in-1 splint. Once the osteotomized mandible is ready for fixation, the CAOS is secured to envelope all surfaces of the dentition (Fig 3). Then, the mandible is positioned into its preprogrammed location by engaging the maxillary dentition using the same splint. The full cuspal coverage of the splint to both dentitions allows it to provide a solid intermaxillary fixation (IMF) and its removal can even be challenging. After rigid fixation of the mandible, the intermediate splint is pulled away and the maxilla is operated on. A final splint is once again snapped into place, guiding the maxilla into its new position using the fixated mandible as a reference (Fig 4).

CASE 2

This case describes the use of CAOS in conjunction with a hybridized orthodontic approach of CAT in the maxilla and traditional fixed appliances in the mandible. It also shows how a segmental maxilla can be positioned using the splint. The patient presents with a Class III malocclusion and an anterior open bite (Fig 5). The planned surgical movements involve occlusal plane correction, asymmetric BSSO setback, and segmental Le Fort I advancement between the laterals and canines. For some anterior open-bite cases, the anterior segment is purposefully not fixated to allow for greater vertical control with elastics on

FIGURE 5. Preoperative cone-beam computed tomograms of case 2, illustrating the maxillomandibular dentoalveolar discrepancy.

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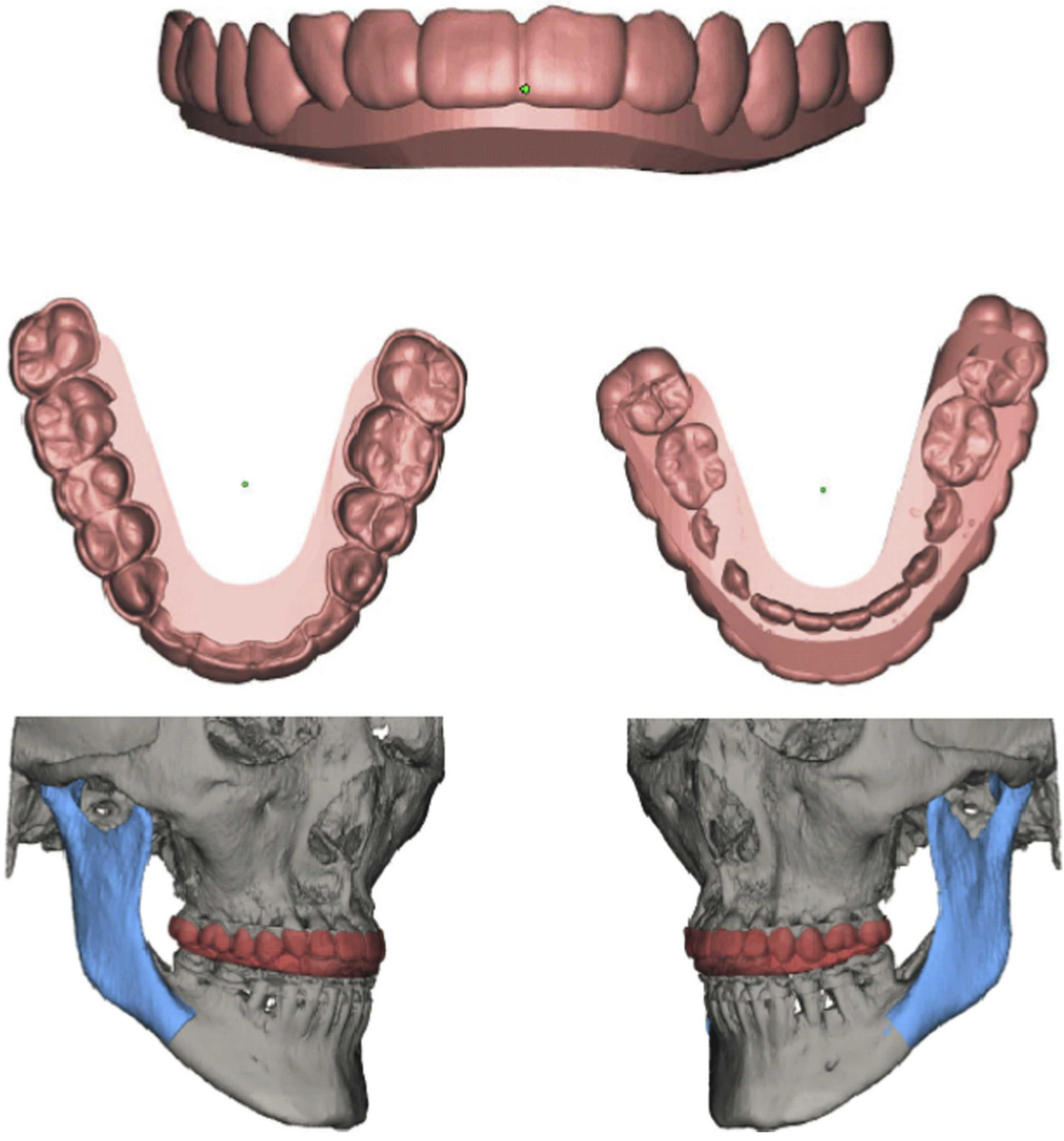

FIGURE 6. Collage of images of intermediate splint used in case 2.

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temporary anchorage devices (TADs) or traditional brackets. The intermediate CAOS is used to the position the mandible and then rigid fixation is applied (Fig 6). The final CAOS is placed after the maxilla is segmented (Fig 7). The CAD/CAM technology produces the CAOS with enough accuracy to allow the segmented arches to "snap" physically into place. There is complete control of the torque of the segments and position (Fig 8). This splint avoids the need for small 28-gauge wires to wrap around each bracket passed through holes of a flat splint. This is time consuming and, more importantly, these wires and short spans limit the amount of control of the dentoalveolar portions. The clear aligner splint described engages the entire crown and segment control is excellent. Postoperative control of the segments can be maintained by TADs or small fixation screws (Fig 9).

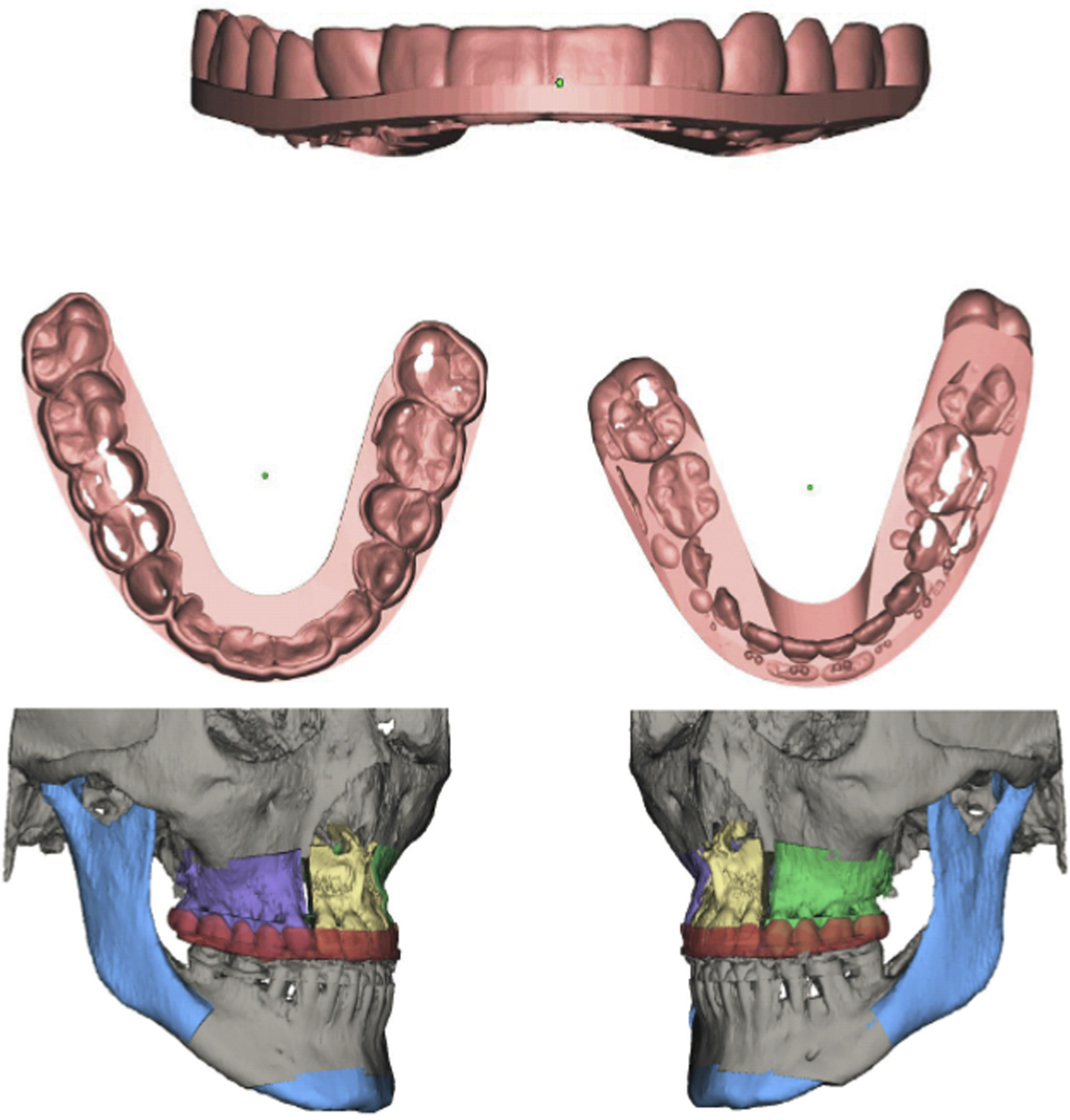

FIGURE 7. Collage of images of final splint used in case 2.

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CAD/CAM MANUFACTURE OF CAOS (SINGLE OR DOUBLE JAW)

The manufacturing progress begins with digitization of the patient's dentition and skeletal structures using a dental scanner and CT or CBCT, respectively. Alternatively, stone models can be submitted to the manufacturers for optical scanning. Although acceptable, direct intraoral scanning is not only faster to upload and send to the manufacturer but also provides a more accurate coronal surface than the scan of a stone model.

The occlusal surfaces of the digitized dentition are matched to the CT or CBCT data by the CAD/CAM manufacturer. Then, virtual surgical planning is completed with the occlusion preferably digitally set by the engineer, although elastomeric or wax registration material also can be used. At the termination of virtual planning, the splints and guide determinations are reviewed.

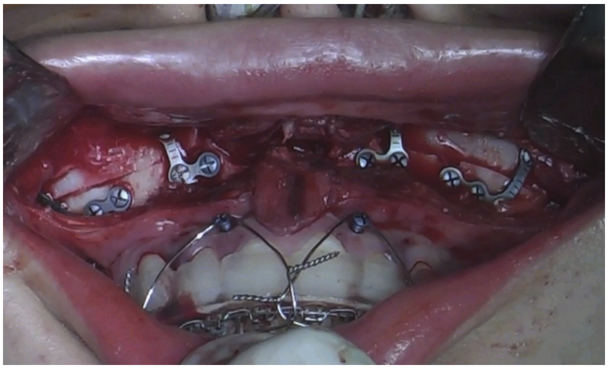

FIGURE 8. Clinical photograph of the final splint in situ for case 2.

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FIGURE 10. Intraoperative view of laboratory-fabricated Essix-type Clear Aligner Orthognathic Splint.

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The design of the CAOS should include a full crown-covered acrylic shell for the dentition. These shells need to be aligned to register an intermediate and final splint relation. Then, the splints need to be cleaned and trimmed and provide some relief at areas that have brackets or attachments left in place.

MANUAL LABORATORY MANUFACTURE OF CAOS (SINGLE JAW)

In cases in which a routine single-jaw surgery is planned, such as an isolated Le Fort or BSSO, the CAD/CAM CAOS might not be a cost-efficient solution. In this section, the authors outline a novel method they created to quickly produce a laboratory-fabricated CAOS (Fig 10). Two Essix-like retainers are made using clear vacuum-formed trays with a thickness of 0.040 inch (or 1 mm). These are trimmed to the gingival margins to obtain full coronal coverage of the dentition. The trays are removed and the planned occlusion is set on a simple hinge articulator.

FIGURE 9. Two-week postoperative image of case 2, depicting elastic control with 6-ounce quarter-inch elastics tied to the fixation screw in the maxilla and surgical hooks of the traditional archwire of the mandible.

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Once the final occlusion is created, the clear trays are placed back on the stone casts. Then, clear denture repair acrylic resin is mixed according to the manufacturer's recommendations. The occlusal surface is wetted with monomer and a roll of setting acrylic is laid between the trays that are fitted on the casts as the articulator is closed into the ideal preset occlusion (Fig 11). Excess acrylic is trimmed once the material has set. A useful maneuver is to lubricate the labial and lingual surfaces of the Essix trays such that the excess resin can be easily removed.

RECOMMENDATION TO ORTHODONTISTS

Orthodontic support is required for this technique, similar to the traditional method of OGS planning. Preoperatively, all aligner attachments should be removed from the surfaces of the teeth to improve fitting of the tray over a smooth surface. Sets of "passive aligners" (2 sets for 1 month before and 2 sets for 1 month after surgery) should be made and given to the patient. The authors have found "post-jump" aligners by CAT manufacturers are not as effective because it can be difficult to predict the exact postoperative occlusion. The dentition can be scanned by the orthodontist or surgeon as soon as the patient has range of motion, usually 2 to 4 weeks postoperatively. Postsurgical elastics are often required to support and guide the surgically corrected occlusion. The elastics are usually through orthodontic TADs, bonded buttons, or directly to the notches on the aligner tray. Their configuration varies based on the presurgical malocclusion, usually in Class II, Class III, or box configurations (Fig 12).

Discussion

The CAOS is a novel maxillomandibular repositioning and fixation device for performing OGS in conjunction with CAT. It has been used in the authors' surgical

FIGURE 11. Laboratory fabrication using acrylic and Essix-type clear retainers to make a Clear Aligner Orthognathic Splint for use in single-jaw cases.

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center for the past several years, with excellent intraoperative handling results. The splint is designed to provide IMF and repositioning of the osteotomized jaw without the use of TADs, IMF screws, wire- or screw-retained arch bars, or buttons and brackets. The CAD/CAM technology is used to create a digitally designed and printed clear tray that adapts to the coronal surfaces of the teeth in an intimate fashion, similar to an Essix retainer. The CAOS has numerous unique advantages compared with traditional splints and some limitations (Table 1). Traditional splints contact only at the cusp tips, mostly because of the limitation of the orthodontic bracket, whereas the large contact surface area of this full cusp-covered splint design allows for binding to the arches in a secure and rigid manner. Therefore, the osteotomized jaw can be positioned according to the occlusal relation (intermediate and final) predetermined by the virtual surgical plan in coordination with the digital manufacturer. The readily "snap-on" nature of the CAOS also allows for accurate and quick positioning in segmental maxillary surgery, without relying on brackets and individual wires tying the teeth to a splint. Future studies are required to assess the retention of the CAOS in cases that require larger maxillomandibular advancements or larger maxillary expansions.

FIGURE 12. Postoperative guidance elastics placed onto buttons with relief cutouts made in the clear aligners.

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The CAOS was designed and created by pushing digital technologies to their greatest benefit. With this appliance, it is possible to improve on many elements of OSG planning for CAT, an area that is underexplored. The CAOS provides excellent adaption and full coronal coverage of the dental arches, allowing for repositioning and fixation of the maxillomandibular complex without the need for wires. Its rigid nature allows for dentoalveolar segments to be positioned with greater control and shorter intraoperative time, especially in multi-piece Le Fort osteotomies.

In conclusion, the intraoperative rapidity in obtaining IMF and its accurate positioning makes the CAOS straightforward, effective, and clinically satisfying. Because a surgically useful splint has been established for this new technology, further studies are currently being performed to analyze the outcomes of these splints in patients with clear aligners.

Table 1. ADVANTAGES AND LIMITATIONS OF CLEAR ALIGNER ORTHOGNATHIC SPLINT

Advantages	Limitations
Accurate and precise seating of entire dentition and arch	Cost of CAD/CAM manufacturing
Rigid and solid IMF for intraoperative positioning when applying rigid fixation	Further studies required on its usage in larger jaw movements
Absence of wires to ligate dentition in IMF	Horizontal and angular aligner attachments decrease the contact surface area of the splint
Absence of small-gauge wires when individually tying segmented arches of the maxilla	Earlier iterations of the CAOS were too rigid and could be difficult to remove
Complete control of individual alveolar segments by controlling the torque owing to complete seating of the crowns during arch alignment	
Rapidly and easily fabricated with any digital planning manufacturer	

Abbreviations: CAD, computer-assisted design; CAM, computer-assisted manufacture; CAOS, Clear Aligner Orthognathic Splint; IMF, intermaxillary fixation.

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