Considerations for treatment of patients undergoing orthognathic surgery using clear aligners

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Clear aligners are an established modality for the treatment of mild-moderate orthodontic malocclusions. However, special considerations, or further adjuncts to treatment, may be necessary when treating challenging discrepancies with clear aligners. One such example is the treatment of patients undergoing orthognathic surgery to resolve dentofacial deformities. As with fixed appliances, treatment of orthognathic surgical patients using clear aligners involves very specific considerations for successful treatment planning, presurgical preparation, and postsurgical finishing and detailing. By suggesting protocols for treatment and precautions to consider, the author desires to provide the clinician with another possibility for treating this group of patients outside of fixed appliances only. (Am J Orthod Dentofacial Orthop Clin Companion 2022;XX:XX-XX)

Clear aligners have been established as an indelible option in orthodontics for their use in treating malocclusions, particularly gaining momentum over the past 20 years. Over time, their usage has increased in adoption to resolve more challenging malocclusions. However, although algorithms and artificial intelligence may increasingly influence the predictability and outcomes of the appliance, sound judgment regarding diagnosis, thoughtful treatment planning, and proper clinical technique will always remain paramount to successful treatment finishes and predictable, repeatable results.[1,2]

The goal of orthognathic surgery is to establish ideal dental occlusion with the jaws to optimize facial aesthetics, using a combination of orthodontics and surgery.[3] Historically, most of these patients have been treated with analog processes, ranging from treatment plan development to the fixed appliances used for treatment. However, in the present day, because of technological advances and increased awareness, more patients are requesting clear aligners as the orthodontic modality used in preparation for orthognathic surgery. Given the digital nature of clear aligners, planning for surgical movements may be virtually performed, allowing for an immediate understanding of decompensation and appropriate customization of movements and the appliance vs an analog process. However, many orthodontists may be hesitant to adopt clear aligners for the treatment of orthognathic surgery patients because of a lack of familiarity with the appliance for this specific use, or similarly, their oral surgeon may equally not be comfortable pursuing the endeavor without fixed appliances for use at the time of surgery.

Simultaneously, there have been advances in 3-dimensional (3D) computer-aided virtual surgical planning (VSP) and computer-aided design and manufacturing of appliances used for surgery.[4] This has led to these technologies being adapted for orthognathic surgery. By leveraging and merging the digital resources now abundantly available to us for clear aligner treatment planning and fabrication, VSP, and 3D printing of surgical splints, systematic processes can be developed and suggested, making treatment of orthognathic surgical patients more predictable and repeatable for all parties involved (Fig 1).

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

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PRESURGICAL PLANNING PROTOCOL

Data acquisition, diagnosis, treatment planning, and bite jump

Thorough orthodontic records are recommended for the diagnosis and treatment planning of proposed dental and

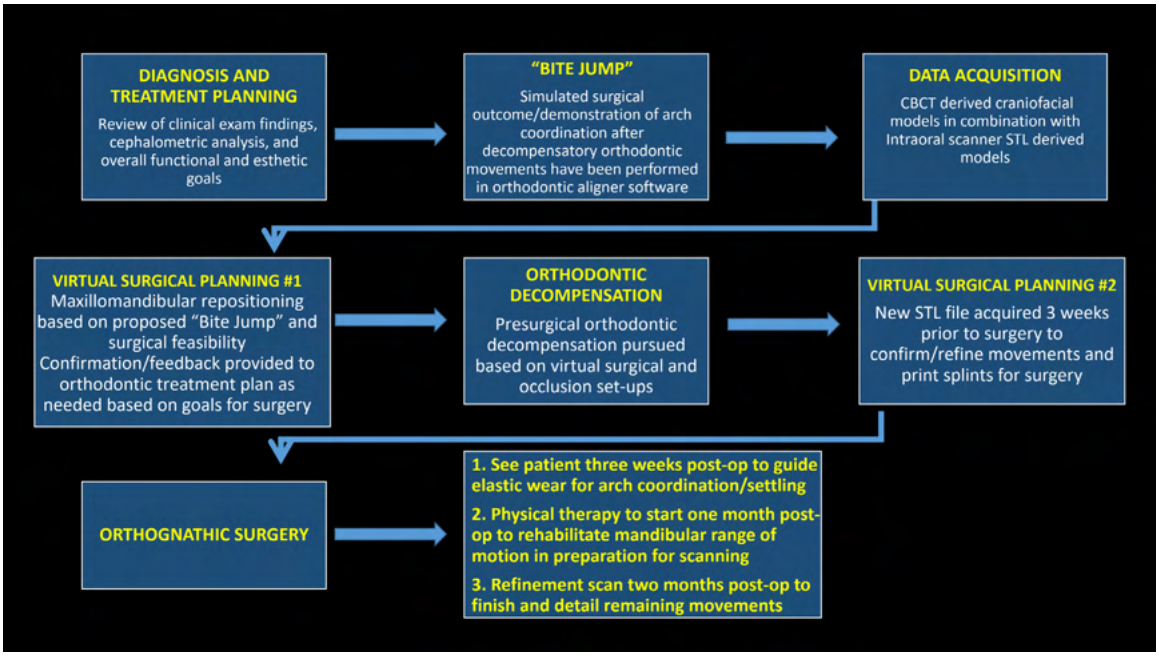

Fig 1. Suggested workflow for treatment of orthognathic surgery patients using clear aligners.

surgical movements. The following records were obtained for the protocol discussed in this paper: full photographic records, a panoramic radiograph, lateral and posteroanterior cephalograms, an intraoral scan, and a cone-beam computed tomography scan. Analyzing the records mentioned above by the surgeon and orthodontist allows for the first of two eventual VSP meetings recommended for any given orthognathic surgical patient.

All multidisciplinary teams have different approaches to their planning processes. This article will focus on the surgical treatment planning protocol that has worked best for our team. Initially, the orthodontist formulates a preliminary proposed ClinCheck outcome (digital treatment plan) using treatment software (Align Technology, San Jose, Calif). This initial ClinCheck will establish the estimated necessary decompensatory movements, based on the orthodontists' diagnosis of the malocclusion, decompensation goals, and visual treatment objectives for the desired esthetic goals and related surgical movements. The surgery itself is visually represented in the software by a singular stage of instantaneous arch coordination after decompensation, referenced as a bite jump (Fig 2). Once this is established, the proposed digital treatment plan will then be reviewed with the oral surgeon to ensure mutual goals are aligned on the first of two live VSP online meetings for any given patient.

Virtual surgical planning

The possibilities offered by allowing the multidisciplinary team to test the soft tissue outcomes of proposed surgical procedures before actually finalizing the treatment plan and appliance fabrication are both practical and advantageous. Maxillomandibular repositioning based on the facial and occlusal goals incorporating the proposed bite jump, cephalometric norms, facial balance, airway considerations, and surgical feasibility is taken into consideration during the first VSP session. Our team uses the services of 3D Systems (Rock Hill, SC) for the VSP sessions and eventual fabrication of 3D printed surgical splints.

During this preliminary session, only the goals and feasibility of the proposed movements are reviewed, and the surgeon either confirms or adds feedback to alter the plan. Overall movements such as extraction vs interproximal reduction (IPR), spacing for restorative, 1 vs 2 step expansions, etc are then either modified or accepted. In our experience, this preplanning process makes it more predictable to achieve optimal occlusion and facial esthetics and not sacrifice one for the other. Presurgical orthodontic preparation to achieve decompensation becomes clear, allowing reviewed movements to be programmed and accepted into the final digital treatment plan for clear aligner fabrication.

PRESURGICAL CLEAR ALIGNER THERAPY

Based on the confirmation of movements from the VSP, decompensation is pursued via the first set of aligners. Careful attention must be paid initially to not being hypnotized by the digital treatment plan, as the digital treatment plan is equally a representation of a force system and a representation of a proposed result or outcome. Often, movements are demonstrated virtually, which are unrealistic or may have poor clinical predictability.[2] Furthermore, the third-party technician often does not understand fundamental orthodontic biomechanics. Hence, it is incumbent on the treating

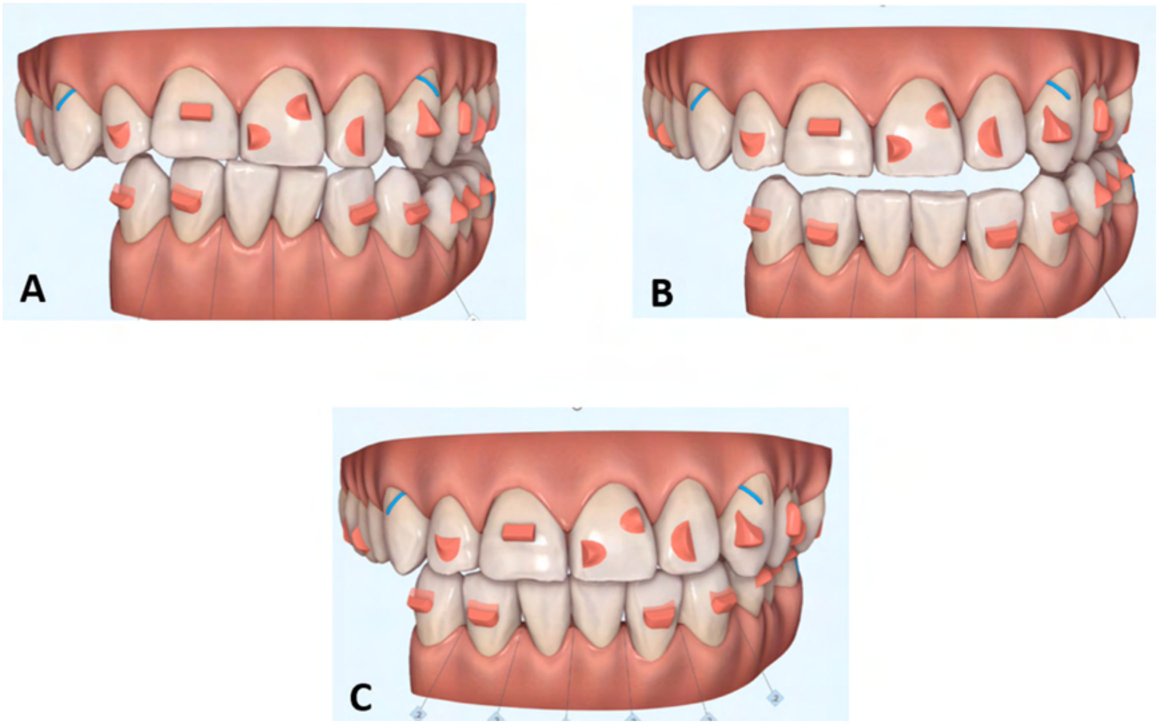

Fig 2. Bite Jump: A visual simulation of arch coordination representing proposed surgical movement in the virtual treatment plan. Below is an example of a bite jump representing a subapical osteotomy of the mandible to move the dentoalveolar base to the patients' right. **A,** Initial stage; **B,** After decompensation; **C,** After bite jump.

orthodontist to overcome these obstacles to properly customize the digital treatment plan with predictable tooth movement, appropriate attachment design, improved staging of tooth movement, and intentional virtual overtreatment of certain movements where needed to properly customize the appliances' attributes and force system for their given patient. Outlined below are some examples for consideration to be careful of during specific surgical decompensatory movements with clear aligners.

Patients with transverse discrepancies

Orthodontic arch development should be limited to biologically acceptable orthodontic movement within the patients' dentoalveolus.[4] Tooth movements are ideally focused on limiting postsurgical interferences from plunging palatal cusps from lack of full correction of the curve of Wilson. In many circumstances, this may mean constricting the maxillary arch and expanding the mandibular arch to worsen the transverse discrepancy in preparation of maxillary expansion surgically. Dental expansion movements should be limited to uprighting the dentition within the existing dentoalveolar complex, so the crowns are positioned over the roots, and bodily movements should be avoided unless the orthodontist has confidence in the predictability of the movement otherwise. If a decision is made to test the limits of dental arch development, attachments on the buccal surface to provide a push surface for engagement of a countermoment to seat the buccal cusp occlusally need to be considered. Otherwise, the buccal cusps may intrude, causing a posterior open bite as a side effect of the forced arch development when posterior teeth are not properly anchored within the aligner. This particular resultant posterior open bite will lead to challenging finishing issues after surgery.

If planning for a 3-piece maxillary surgery, attention should be paid to opening spaces for osteotomies, usually distal to the maxillary lateral incisors, and to diverge the roots of the canines and lateral incisors away from each other, respectively. Attachments specific for root movement (i.e., long vertical or twin attachments) should be placed to provide the proper push surfaces to facilitate the moments needed for the desired movement. Postsurgical detailing focuses on then moving the roots back toward each other for parallelism in refinement. The osteotomy preparation site spaces represented on the treatment plan tend to fall short of what is predicted virtually; hence, this requires an exaggeration of the space opened in the digital treatment plan to more accurately achieve what is desired clinically. Another possibility would be to change aligners slower than usual until the clinical outcome matches the desired outcome required for safe osteotomy of the sites to account for the lag in predicted tooth movement.

Patients with vertical discrepancies

Tooth movements with high relapse potential should be avoided during decompensation, specifically extrusive movements that can be leveled surgically. One such example would be the extrusion of anterior teeth in open bite tendency patients. It is recommended to level such patients into their respective initial varying planes of occlusion and to subsequently level the planes with surgery.

Tooth movements to level the curve of Spee in deep overbites should be overtreated virtually because of the lack of full clinical expression of movements such as anterior intrusion in clear aligners. Also of note, it may actually be more advantageous for particular patients to level the curve of Spee postsurgically when there is a desire to increase the posterior facial height.[5] In either circumstance, attention must be paid to focusing on attachments (horizontal or retentive type attachments) in the posterior and anterior segments for adequate anchorage to level the curve of Spee and develop a force system within the aligner to facilitate predictable leveling.[6] This involves establishing a pronounced reverse curve of Spee to level the arch in the digital treatment plan, finishing the proposed outcome with heavy posterior contacts and zero anterior centric contacts.

Patients with anteroposterior discrepancies

Decompensation of the initial occlusion is often required to properly address anteroposterior discrepancies. Decompensation aims to achieve proper facial esthetics and a subsequently balanced occlusion after surgery. Failure to decompensate the patient presurgically will lead to improper occlusion and facial esthetics.[7] Planning for decompensation in surgical correction of anteroposterior discrepancies involves the evaluation of many variables during the treatment planning process. One of the advantages of digital treatment planning is readily accessible tools at the clinician's disposal, such as superimposition tools or grid rulers to gauge the degree of movements presented. Another useful tool is the instant demonstration of the predicted Bolton analysis. This number should be considered, as any clinically significant discrepancy can influence decisions and methods for decompensation. Resolution of any Bolton discrepancy can further facilitate decompensation via IPR and/or opening of space for restorative needed to achieve certain goals. Furthermore, addressing Bolton discrepancies improves the probability of idealized occlusion during the finishing and detailing phases after surgery. Based on the primary virtual surgical plan and confirmation of movements, the following considerations may be needed:

1. Flaring or labial movement of incisors: This may be accomplished via leveling the curve of Spee, the use of elastics, or opening of space to address potential Bolton discrepancies. When using elastics, buttons (precision button cutouts) directly bonded to teeth or hooks (precision cuts) manufactured into the aligner may be used. Attachments for retention are recommended on teeth in which elastic features for anchorage are used to negate any potential unintended consequences of prolonged elastic use (ie, tooth movement within the aligner or eventual lifting of the aligner off of the teeth).
2. Uprighting or lingual movement of incisors: To decompensate presenting dentoalveolar compensations of the patient's underlying skeletal discrepancy, IPR or extractions may be required to upright incisors. Again, elastics may be needed to help facilitate this movement. If IPR (or any space closure in general) is needed, it is important to note that the resultant space closure from IPR may deepen the bite clinically. This side effect is not shown in the digital treatment plan and may lead to an unintentional loss of effective overjet and a loss of anterior torque clinically. Henceforth, both bite opening and lingual root torque should be overtreated when space closure or general retractive movements of the anterior dentition are shown in the presurgical treatment plan. This is facilitated by finishing with heavy posterior contacts, zero anterior contacts, and overtreating the lingual root torque demonstrated anteriorly. As with any overtreatment in orthodontics, how much will depend on the overall degree of movement needed, predisposing relevant biologic factors, and the clinician's personal experience. If extractions are needed for decompensation of incisors, it's the author's suggestion to use fixed appliances for their superior ability to close extraction spaces, control root parallelism, level the curve of Spee, and to control anterior root torque more expediently and predictably.

AFTER PRESURGICAL DECOMPENSATION IS COMPLETE

We recommend at least two months of passive aligner use before surgery. These are either multiple aligners fabricated to the last active stage of the presurgical treatment plan or a more rigid retainer (0.040-in thermoformed retainer) ordered to this final stage. In this instance, the use of the word passive is a misnomer because of the expression of lag that occurs of many movements within the aligner. Prolonged use of these aligners allows for further expression of important decompensatory movements such as leveling of the curves of Wilson and Spee. This helps to reduce the likelihood or significance of occlusal inferences when coordinating the arches at the time of surgery. Once proper decompensation has been achieved, the second and final presurgical VSP is then performed. This will allow confirmation of surgical movements and fabrication of 3D printed surgical splints.

For the technique used in this paper, attachments are removed from the canines to the first molar in both arches. Button cutouts are fabricated in the location of the removed attachments (Fig 3). Doing this facilitates easier removal of

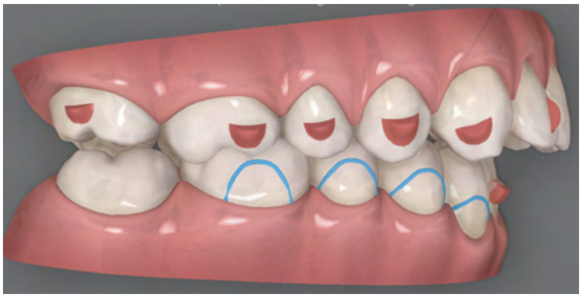

Fig 3. Example of a patient's mandibular passive aligners prepared for surgery. The maxillary arch was undergoing expansion hence no maxillary passive aligner. Precision button cutouts were programmed into the aligners, with requests to remove attachments on the same teeth to allow easier aligner removal after surgery. This technique also increases the ease of bonding buttons for elastics as needed postsurgery.

the aligners by the patient postsurgery as the aligners are far less retentive without these attachments. Furthermore, this protocol allows for simplified bonding of buttons as needed postsurgery, as no handpiece will be needed to remove composite, which is challenging with the limited range of motion of most patients after surgery. The decision not to bond elastic buttons before surgery reduces the risk of accidental breakage and loss of a button at the time of surgery, which may present complications. Hence, the patient enters the surgery with no elastic buttons, brackets, wires, or hardware placed prior. When in surgery, two temporary skeletal anchorage devices (TSADs) are placed in each quadrant for use during intermaxillary fixation of the bony segments at the time of surgery. These same TSADs are then used for intermaxillary elastics after surgery for 6 weeks. It is recommended that the TSADs be placed mesial of the first molars and distal of the canines. Placing TSADs mesial to the canines increases the risk for gingival irritation from elastic wear after surgery as the elastics will cross the curvature of the archform and create tissue impingement (Fig 4).

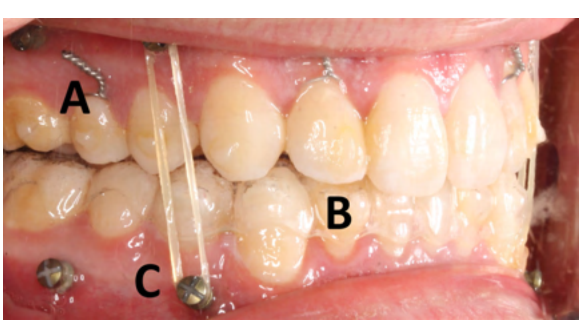

Fig 4. Photograph showing several items. Ligature of the patient's maxillary palatal splint into place to support healing of surgical expansion **A,** mandibular Invisalign tray worn to prevent relapse, with button cutouts present with previous attachments removed for ease of bonding buttons at a future appointment when TSADs are removed **B,** and TSADs used for intermaxillary elastics **C**.

THREE-DIMENSIONAL PRINTED SURGICAL SPLINTS

The increased usage of VSP and computer-aided design and manufacturing of appliances has allowed the precise fabrication of surgical splints.[8] A summary of 3D printed splints used during or after surgery is as follows (Fig 5):

1. Intermediate splint: Positions the mandible against the maxilla after bilateral sagittal split osteotomy. This splint corrects pitch, yaw, and roll with anteroposterior positioning of the mandible, allowing for rigid fixation of the proximal segment to the distal segment. Special attention is given to seating condyle properly within the fossa. The mandible is operated on first for the method described in this paper for bimaxillary surgery.[9]
2. Final splint: Determines the final position of maxilla against the already repositioned mandible
3. Palatal splint: Used with segmental maxillary expansion surgery. Facilitates healing and maintenance of expansion of the maxillary segments postsurgically. This splint stays affixed for 3 months at a minimum and is ligated through the interdental papilla and contact points of the teeth for fixation.
4. Invisalign guiding splint: Postsurgical splint for surgeries involving repositioning without expanding the maxillary arch. This splint is used for 2-3 weeks postsurgery to guide the patient into occlusion during the recovery phase and may take the place of the aligners. Primarily used to retrain the musculature to avoid an acquired bite and is used in conjunction with elastics. The splint has open occlusal holes, allowing more approximate evaluation of the occlusion in contrast to having two aligners between the dentition. Once the surgeon and orthodontist are comfortable with the occlusion, the patient may move back into aligners again instead of the splint during recovery.

POSTSURGICAL CONSIDERATIONS

After surgery, the patient is requested to place their aligners back in their mouth as soon as possible, ideally no more than 2 days after surgery. The orthodontist observes patients within 2 weeks to confirm proper use of elastics from TSADs and is then subsequently scheduled on a 2-3-week basis to continue to monitor healing and elastic use. The use of elastics from TSADs is limited to 6 weeks only because of the increased potential of discomfort to the patient from potential gingival irritation because of TSADs normally being placed in the mucosa for surgical patients. Physical therapy is initiated 1-month postsurgery to release musculature and increase mandibular range of motion to allow scanning for additional aligners. As soon as TSADs

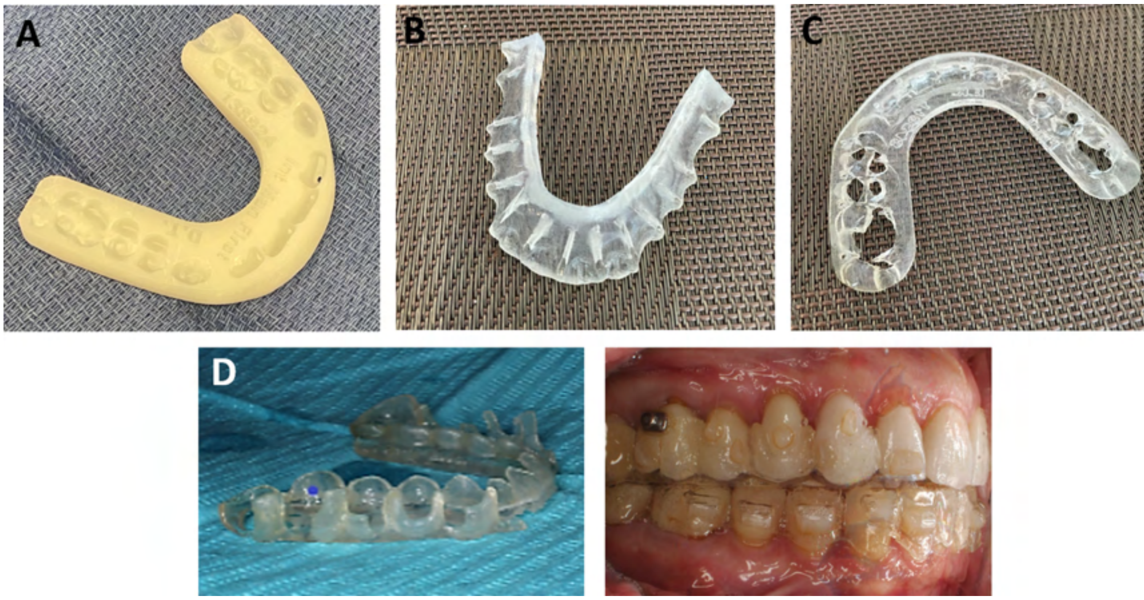

Fig 5. A demonstration of the various 3D printed splints may be used as part of the orthognathic surgery process. These splints are fabricated on the basis of the movement prescribed as part of the VSP. **A,** Intermediate splint: used for mandible-first surgery, positioning the mandible against the uncut maxilla. **B,** Maxillary palatal splint: showing holes for ligation of the splint to maintain expansion after surgery. Ligatures pass through the pilot holes shown, through the interdental papilla, and around the interdental contact points to rigidly tie the splint into place. The ligatures and splint are removed 3-4 mo after surgery to allow for primary healing of bone. **C,** Final splint: determines the final position of the maxilla against the already repositioned mandible. **D,** Invisalign guiding splint: postsurgical splint that may be worn instead of or combined with an opposing aligner. This splint helps guide the patient's occlusion to avoid an acquired bite after surgery.

are removed at the 6-week appointment, buttons are now bonded in the previously programmed aligner button cutout areas as needed to continue elastic wear interdentally. Usually, at the 2-month mark, a refinement scan is taken to order additional aligners when needed for detailing.

An alternative protocol to scanning for more aligners after surgery, if desired, would be to scan the patient before surgery after they have been fully decompensated. This would be done to ensure additional aligners are delivered as soon as possible postsurgery to immediately facilitate any perceived needed finishing and detailing. In theory, this helps take advantage of the initiated regional acceleratory phenomenon from surgery more readily. The proposed total surgical movements are estimated in the digital treatment plan on the basis of the decompensation scan. Any presenting arch coordination discrepancies could then be further detailed after surgery via these new aligners. This approach is only amenable for 1 or 2 jaw surgeries that do not involve expansion of the maxillary arch. An exact prediction of the postsurgical anatomy with the expansion is not likely to be feasible and will lead to an ill-fitting maxillary aligner.

When segmental expansion of the maxillary arch is needed, we recommend the use of a maxillary palatal splint, ligated through the interdental papilla, to be worn for a minimum of 3 months.[10] The splint facilitates primary healing of bone while acting as a retainer to prevent relapse of maxillary dental and skeletal movements by contacting the lingual aspect of all of the maxillary teeth. The patient concurrently wears their mandibular aligner postsurgery to retain the mandibular dentition. At the 3-month mark, the maxillary palatal splint is removed, and a same-day thermoformed retainer is made, with coverage on the palate, to further promote maxillary healing while additional aligners are being fabricated. A scan is then obtained if needed for additional aligners.

FINISHING AND DETAILING

In addition to any customary detailing, special attention should be paid toward eliminating any presenting interferences to allow for the remaining occlusion to come into contact to settle. Technicians incorrectly tend to extrude posterior teeth together to the presenting interferences vs actually eliminating the interferences with intrusion when indicated, which does not address the etiology of the presenting finishing concern. Instead, this may add further complication as extrusion of posterior teeth is challenging with an aligner. If posterior or anterior interferences are diagnosed during the refinement scan, our primary instructions to the technician are to eliminate any apparent interferences by leveling the curves of Wilson and Spee accordingly and to then show a bite jump for arch coordination. Again, a bite jump, or simulation of arch

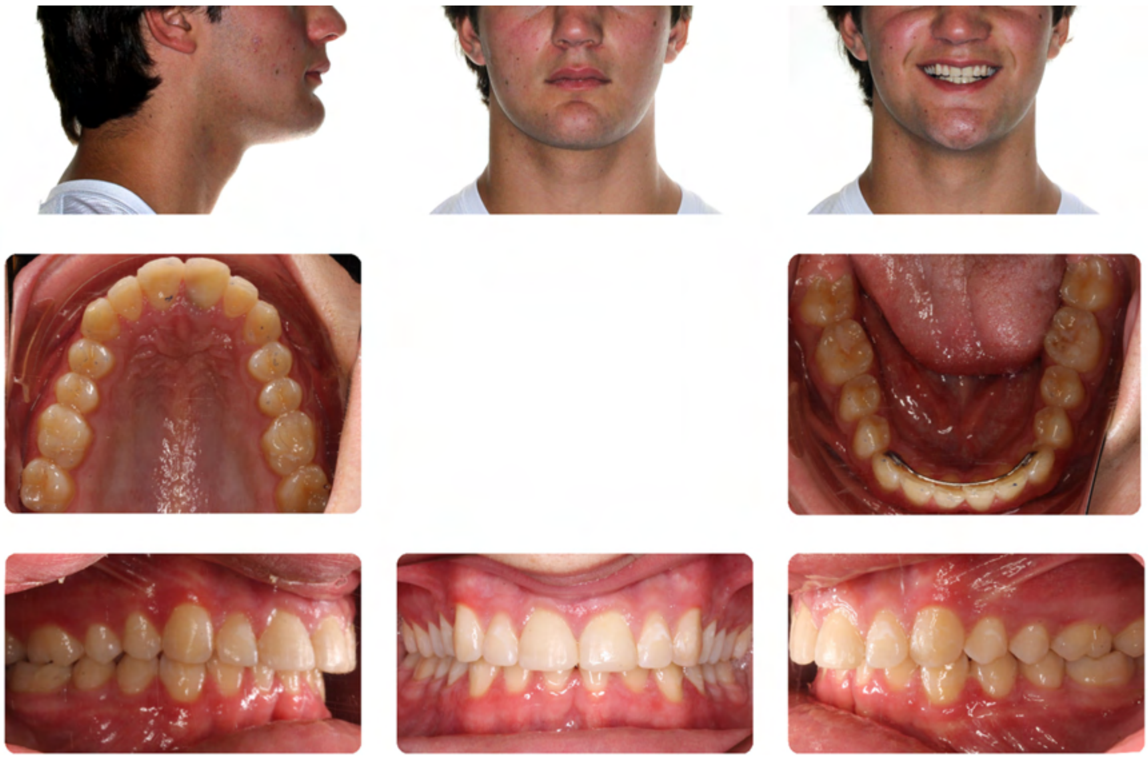

Fig 6. Patient example. Initial photographs of an 18-year-old male with a deepbite, Class II Division 1 skeletal malocclusion.

coordination representing the removal of these interferences, is a demonstration of a singular stage or instance of arch coordination and full contact of the dentition. Removal of these presenting interferences often leads to hinge movement of the mandible anteriorly and may demand that the virtual simulation of the bite jump to be guided clinically by elastics should there be any anteroposterior or midline changes. When closing any residual osteotomy spaces, or any other spaces that may be present, or if IPR is added, attention should be paid to avoiding any bite deepening from space closure with overtreatment of anterior intrusion and anterior lingual root torque in the virtual plan.

RETENTION

Clear aligners can make for excellent retainers when worn properly. However, with maxillary expansion, we recommend Hawley retainers, or full palatal coverage Essix retainers, in the maxilla for more rigid retention of transverse correction.

CASE EXAMPLE

An 18-year-old male presented with a Class II Division I skeletal malocclusion. He had a history of orthodontic treatment (Fig 6). The patient was still concerned with the lack of resolution of his overjet after his prior treatment. His chief complaint was to resolve his overjet and improve facial esthetics. Orthognathic surgery for mandibular advancement was suggested for an ideal outcome. Given his history of fixed appliances, the patient desired Invisalign for his second round of orthodontics.

A ClinCheck was developed on the basis of treatment goals. The focus of the ClinCheck was to level the lower curve of Spee to allow for proper arch coordination at the time of mandibular advancement. Attachments to prioritize anchorage for anterior intrusion were specifically selected on the mandibular arch. IPR was added to prevent excessive flaring of the lower during leveling and alignment. Iowa spaces were also developed to facilitate proper posterior interdigitation during surgery. The bite jump demonstrated proper coordination of the arches after decompensation via a bilateral sagittal split osteotomy (Fig 7). An initial VSP was performed to confirm movements proposed with the surgeon before accepting the digital treatment plan. All movements were confirmed with no changes, and the aligners were subsequently fabricated.

Forty-six aligners were used to decompensate the patient with weekly changes, with IPR performed at aligner 15. Records were updated demonstrating decompensation before surgery (Fig 8). A second VSP was performed to confirm surgical movements and fabricate surgical splints (Fig 9). A reduction genioplasty was planned for ideal facial esthetics on the basis of

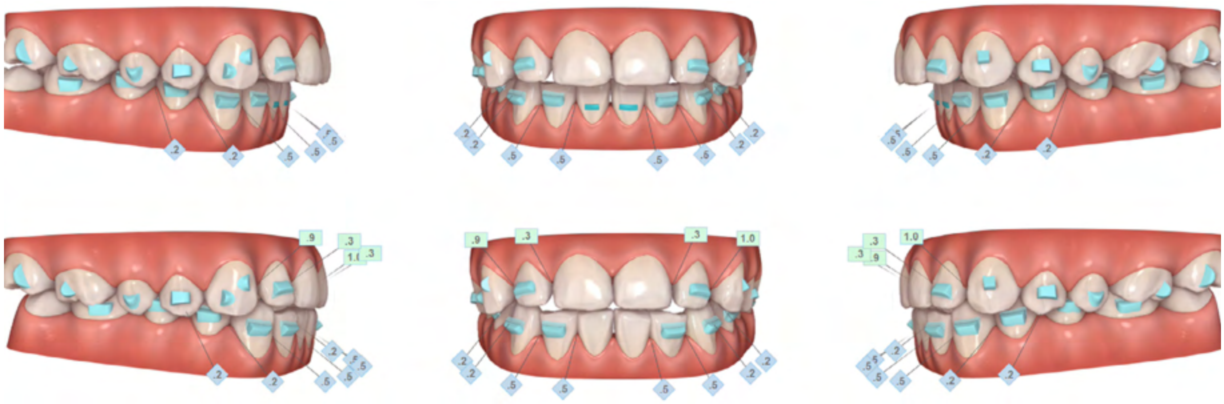

Fig 7. Screen captures of a Clincheck pre- and post-bite jump, demonstrating arch coordination via a proposed surgical movement.

Fig 8. Presurgical decompensation photographs demonstrate increased overjet and overbite improvement in preparation for mandibular advancement surgery.

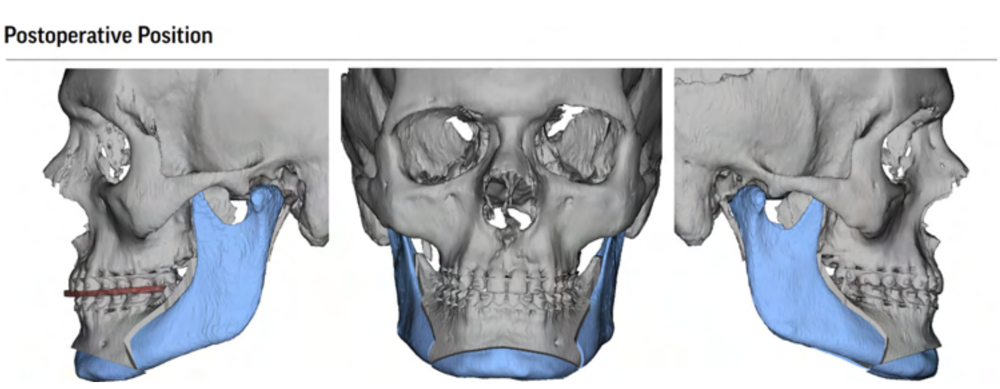

Fig 9. VSP report, showing the postsurgical proposed position after mandibular advancement, including the final surgical splint.

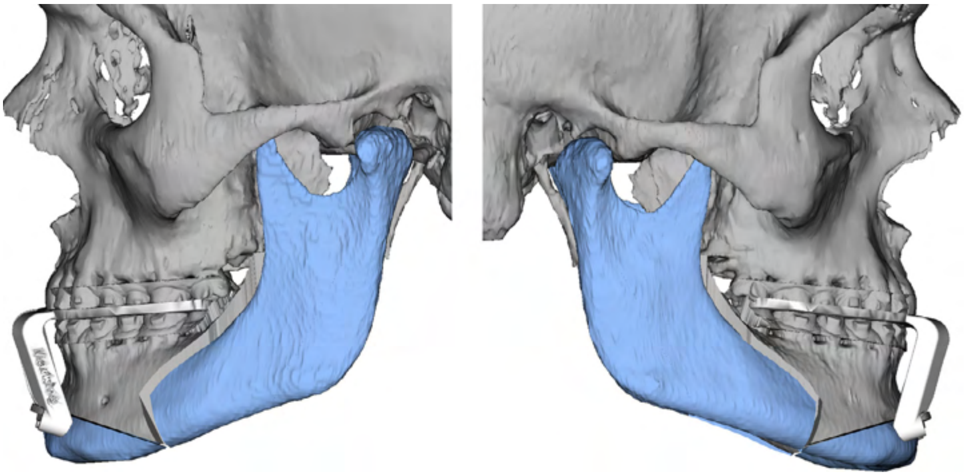

Fig 10. Genioplasty marking guide from VSP report, demonstrating a guide for reduction genioplasty.

Fig 11. Pictures of Invisalign guiding splint in and out of the mouth. This removable splint is worn on one arch, with Invisalign on the opposite arch, to guide postoperation healing and occlusion.

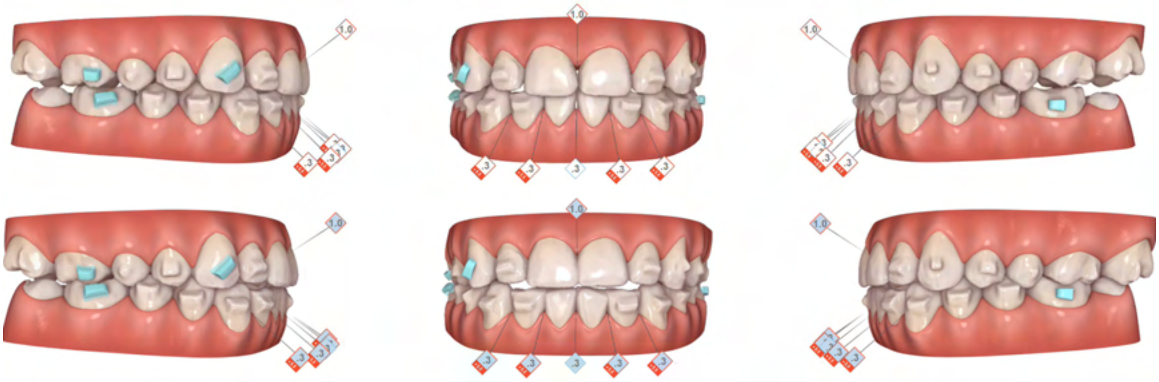

Fig 12. Refinement/additional aligners screen capture, showing initial and final stages for detailing of the occlusion.

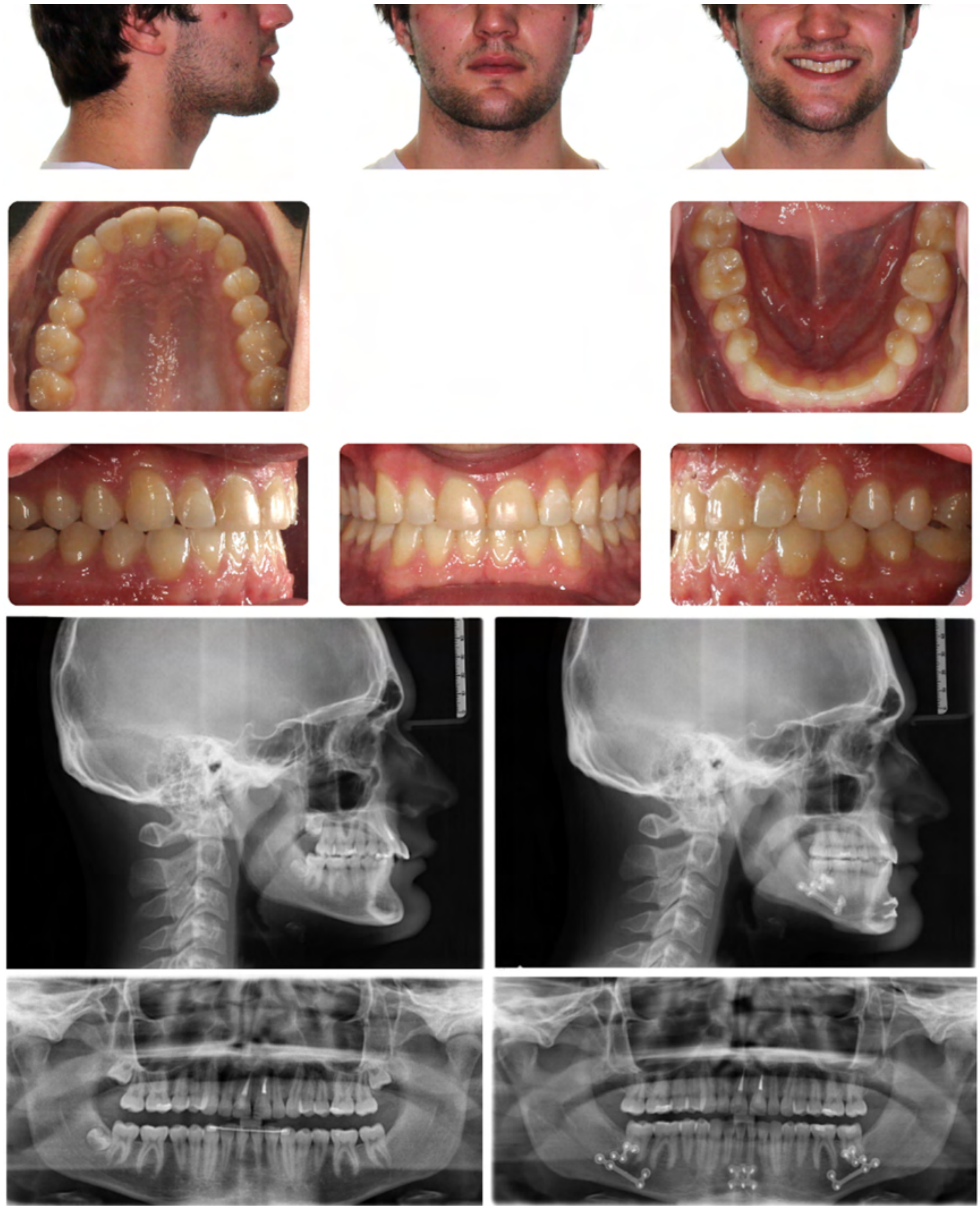

Fig 13. Final records demonstrating the final composite photographs and comparison panoramic and cephalometric radiographs pretreatment and posttreatment.

the proposed VSP (Fig 10). For this particular patient, a final splint for maxillomandibular repositioning at the time of surgery and an Invisalign guiding splint for use postsurgery were fabricated (Fig 11).

A refinement scan was obtained for additional aligners 2 months after surgery and accepted a new ClinCheck plan. In refinement, IPR was performed to reduce the previous composite placed to address a maxillary midline diastema, and mandibular IPR was preformed to detail the patient's resulting overjet. Given that IPR was added to maxillary and mandibular arches, the last stage of the ClinCheck was purposefully finished with a slight anterior open bite for zero centric contacts. This intentional overtreatment was done to clinically combat the bite deepening effect of the IPR added (Fig 12).

Twenty-six aligners were needed for finishing. At the end of refinement, all attachments were removed and final records updated (Fig 13). The patient was scanned for Vivera retainers (0.040-in thermoformed retainers). The recommended retention protocol was for 6 months full-time retention and then to bed lifetime. Overall, the patient was seen for nine office visits (not including retention), with a total treatment time of 20 months.

CONCLUSIONS

There are certain advantages to the patient and treating doctor when adopting clear aligners to facilitate orthognathic surgical correction of skeletal malocclusions. The psychology of the process may be more palatable for many adults with clear aligners vs braces, especially because many have already experienced braces before. Orthognathic surgery is already a daunting proposition for most adult patients, especially if they need to wear fixed appliances through the process. The advent of using clear aligners to manage their treatment makes this process more reasonable for many. Furthermore, controlling oral hygiene during treatment, especially immediately after surgery, is more achievable with clear aligners than fixed appliances.

Logistically, fewer appointments are generally needed to treat patients with clear aligners, with less overall chair time needed, allowing for increased convenience during the treatment process. The end-to-end digital patient experience allows for certain predictabilities that are otherwise hard to realize in an analog world, especially with recent announcements of integration of CBCT use into digital aligner treatment planning processes. This benefits all parties involved as increased precision may be achieved in the digital ecosystem, from treatment planning to fabrication. Looking back 10 years from now, one could even envision that adoption of clear aligners for orthognathic surgery may be more routine than exotic.

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