Invisalign® aligner therapy for the orthodontic treatment of bimaxillary dental protrusion with first bicuspid extractions and maximum anchorage—a preliminary report.

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The prevalence of dental protrusion is high in China, and because of this, the rate of premolar extractions is also very high among orthodontic patients in China—about 60%. Orthodontic treatment of bimaxillary dental protrusion is typically characterized by the extraction of permanent first bicuspids, in order to facilitate the retraction of the anterior teeth and reduce the protrusive appearance of the facial profile. To maximize the amount of facial esthetics improvement, the presence of minimal crowding is desirable, so that most of the extraction space can be used for anterior retraction instead of for aligning the teeth. If moderate to severe crowding is initially present, then little extraction space for retraction is left after the crowding is relieved, and the ability to flatten the facial profile becomes reduced.

Maximum orthodontic anchorage of the posterior teeth is also desirable when treating bimaxillary dental protrusion patients with first bicuspid extractions. If mesialization of the posterior dentition can be minimized, then the retraction of the anterior teeth can be maximized. However, the greater the distance the anterior teeth have to travel distally, the greater the risk of unwanted distal crown tip in the canines. The teeth distal to the extraction space are also at risk for unwanted mesial tip during anterior retraction, as a result of the reciprocal forces generated on the posterior teeth during space closure.

The treatment of dental protrusion with clear aligners such as Invisalign is a promising esthetic orthodontic solution. However, several known challenges exist when using clear plastic aligners to treat bicuspid extraction cases. The first is preserving posterior anchorage so that the posterior teeth do not move mesially during anterior retraction. The second challenge is avoiding mesial tip of the posterior anchor units in the event that mesial drift is unavoidable. The third concern is retracting the canines without tipping the crowns distally. Finally, maintaining positive incisor inclination along with adequate lingual root torque during anterior retraction is also a challenge.

To address these concerns in the past, doctors have tried adding bonded power arms, TADs, and orthodontic elastics in combination with aligner treatment. However, the use of elastics, TADs, and/or power arms may reduce the overall visual esthetics of the aligner treatment, and whenever orthodontic elastics are used, patient compliance with wearing the elastics becomes critical for treatment success.

The Invisalign system now offers several new features (called Invisalign G6 features) for the treatment of bimaxillary dental protrusion with first premolar extraction. These features are designed to address the clinical challenges associated with bicuspid extraction treatment while maximizing the esthetic advantages associated with clear aligner treatment. The first feature is the SmartForce™ optimized attachment design coupled with SmartStage™ aligner activations for the canines and posterior teeth. According to Align Technology Inc. (the manufacturers of Invisalign aligners), SmartStage technology is an advanced algorithm that determines the shape of the aligner at every stage so that the aligner engages with the teeth and the active surfaces of the attachments to apply the necessary force system. More specifically, the molar and 2nd premolar attachments are designed to minimize both mesial tipping of the posterior teeth as well as slippage of posterior anchorage during anterior retraction. The canine attachments are also designed to create anti-tip forces during canine retraction. To maintain lingual root torque during incisor retraction, Power Ridge® features are automatically built into the aligners as concavities near gingival area of the incisors.

*Xu T, Liu Y, Yang M, Huang W. Comparison of extraction versus nonextraction orthodontic treatment outcomes for borderline Chinese patients, AJO-DO 2006; 129:672-7.*
Force moments when SmartForce optimized attachments are used with Invisalign aligners (arrows are for illustrative purposes only). Image provided by Align Technology, Inc.

Some Invisalign features are designed to enhance the esthetics of the patient experience without compromising functionality. For example, newly redesigned pontic spaces have both an aesthetic and functional benefit. Not only does each pontic space in the aligner allow a tooth-colored material to be added in order to hide the extraction space and optimize appliance esthetics, each pontic space is also custom-designed to maximize the engagement of each appliance to the teeth adjacent to the extraction space. During the initial ClinCheck® setup phase, the teeth planned for extraction can also be deleted virtually from the scanned dentition. This way, the actual extractions in the patient can be performed after the aligners arrive from the lab, so that the patient does not have to show any unsightly extraction spaces when smiling.

Other Invisalign features are designed for doctor and staff convenience, so that orthodontic auxiliaries commonly used with bimaxillary dental protrusion patients can be integrated into aligner treatments more efficiently. For example, orthodontic auxiliaries such as bonded power arms can be easily incorporated into Invisalign aligner treatments if needed. Power arms are useful for bodily movement of teeth during extraction space closure and also useful when roots are unfavorably positioned and bodily translation is desired. Power arms position the force vector created by the elastic closer to the center of resistance of the tooth.

The attachment template provided by Align Technology can now be used to bond power arms on the teeth desired, so that the aligners and power arms can work together without the doctor having to manually trim each aligner. Elastics can then be connected from power arm to power arm, from power arm to elastic hooks cut into the aligner, or from power arm to bonded button.

Temporary anchorage devices (TADs) can also be used with Invisalign treatments when absolute anchorage is desired. Posterior TAD placement may be considered when retracting incisors with minimal dental crowding present, in order to minimize mesial tipping of the posterior teeth due to reciprocal forces generated during anterior retraction. TADs can be connected to a bonded anchor point such as a button or a bracket, using either an orthodontic elastic or a ligature wire. This keeps the tooth attached to the TAD from slipping in the mesial-distal direction while the anterior teeth are being retracted. Invisalign aligners can be manufactured with precision cutouts for buttons, where the gingival line of each aligner is trimmed so that buttons can be bonded to the teeth without the aligner edges interfering.

CASE EXAMPLES

The following four cases introduce some of the new Invisalign features available for the treatment of bimaxillary dental protrusion with first bicuspid extractions and maximum anchorage. Clinical insights gained from treating these patients with Invisalign aligners are also highlighted.

Case #1

CLINICAL INSIGHT – Root parallelism in bimaxillary protrusive patients can be maintained during incisor retraction and extraction space closure.

Patient’s chief concern: Protruded lateral profile.

Diagnosis

- 31 year old female
- Right side: Molar Class 3, Canine Class 2 (moderate)
- Left side Molar Class 1, Canine Class 1
- Upper arch: Mild crowding
- Lower arch: Mild crowding
- Bimaxillary protrusion, retruded mandible, lip incompetence, excessive overjet.
- 4.5 is missing and 4.1 is a ceramic crown restoration.
- Upper midline is coincident with the facial midline.
- Key cephalometric values:
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**Initial Images**

**Treatment Description**

Treatment plan: Extract all remaining first bicuspids (1.4, 2.4, 3.4).

ClinCheck set-up details: No mesialization of the upper posterior teeth and the lower left posterior teeth in the set-up. 9 mm of upper anterior teeth retraction was planned. The staging pattern for retraction of the anterior teeth was first to retract the canines by one third of the extraction space, and then en masse retraction of the remaining anterior teeth afterwards. The new Invisalign optimized attachments were used on the upper canines, and 0.75 mm thick x 4.0 mm tall vertical rectangular attachments were used on the lower canines. Upper and lower Power Ridge features were built into the incisor areas of the upper and lower aligners to maintain incisor inclination during anterior retraction. These were automatically placed when lingual retraction of the incisors was detected in the plan.

Stage #2 of the patient’s ClinCheck set-up. Invisalign optimized attachments are in the upper arch and vertical rectangular attachments are in the lower arch. The gray areas are pontic spaces where the extraction spaces are expected, since the patient’s teeth are not extracted until after the set-up is approved.
Stage #11 of the ClinCheck setup with the Power Ridge feature on the facial and lingual sides of the upper incisors (the locations of the feature are indicated in blue).

Actual appearance of the Invisalign Power Ridge feature when the aligners are worn. In this patient, the feature is present on all of the upper and lower incisors.

Treatment progress images (after 8 months, 16 stages, 2 weeks of wear for each aligner):

Progress panoramic radiograph taken after 16 months (32 stages)

Treatment Notes
Attachments were bonded after aligner #1 was worn, but before aligner #2 was given, so that the patient would have a few weeks to get used to wearing the aligners before the attachments were added. A TAD (Zhongbang Company, China) was also placed between 4.4 and 4.6 before aligner #2 in order to increase the anterior anchorage when distalizing the lower right molars into Class 1. A composite button was bonded to the aligner near the lower right canine, and 1/8” 3.5 oz. elastics used to connect the button to the TAD. Elastics were changed daily. Three additional TADs were later placed between 1.6/1.7, 2.6/2.7, and 3.6/3.7 in order to increase anchorage support of the posterior teeth during retraction of the anterior teeth. These TADs were also connected to buttons on the aligner using 1/8” 3.5 oz. elastics. A progress panoramic radiograph taken after 16 months (32 aligners) reveals good root parallelism of the teeth adjacent to the extraction sites.

Case #2
CLINICAL INSIGHT – When closing extraction spaces, Invisalign G6 SmartForce attachments are able to control the root tip of the canines during anterior retraction.

Patient’s chief concern: Protruded lateral profile.

Diagnosis
• 27 year old female
• Right side: Class 1 molar and Class 1 canine
• Left side: Class 1 molar and Class 1 canine
• Upper arch: Mild crowding
• Lower arch: Moderate crowding
• Bimaxillary protrusion. Upper midline is coincident with the facial midline.
• Normal anterior overjet and overbite.
• Crown of 4.3 is tipped distally, with the canine root tipped mesially.
• Key cephalometric values:

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<td>Nasolabial angle</td>
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**Treatment Description**

Treatment plan: Extract 1.4, 2.4, 3.4, 4.4.
ClinCheck set-up: Maximum anchorage in the upper and lower arch, with TADs placed before stage #24 in the labial alveolar bone between the first and second molars (one per quadrant). SmartForce attachments were automatically placed on the lower right canine due to the angulation change planned during treatment. Staging pattern: No mesialization was set up in the upper posterior and lower left posterior teeth. 9 mm of upper anterior teeth retraction was planned, with retraction of the canines first by one third of the extraction space, and then en masse retraction of the anterior teeth for the remaining distance.

The Invisalign G6 SmartForce attachment design for the lower right cuspid at the initial (pre-treatment) stage.
Treatment progress images (after 17 months, 49 stages, 10 days of wear for each aligner):

A progress panoramic radiograph taken after 18 months (42 stages) shows excellent root parallelism, including the lower right canine.

Positive changes in the patient’s facial profile have been achieved even though the treatment is not yet finished. Lower incisor leveling and additional lingual root torque in the lower arch is still needed. The anterior interference from the increased overbite needs to be reduced so that Class 2 elastics can be used to help correct the Class 2 developing on the left side to Class 1, by allowing the lower left side to advance farther forward. A new aligner feature designed to address unwanted anterior extrusion from lingual tipping during retraction was introduced after this case was started and is explained in the discussion section. The gingival irritation observed in the area of 1.4 was the result of slight impingement with the margin of the aligner.

The TADs were initially connected with elastic chain to buttons bonded on the canines, but the elastic chain was discontinued after only 4 weeks because the canines started to rotate too much, especially when the aligners were removed for eating and brushing, which causing the aligners to not fit well. To improve the slight mesial tip observed in the upper molar crowns, the upper molars will be distalized during refinement. For anterior anchorage control, the upper TADs will be connected with elastic chain to buttons bonded to the canines, but vertical attachments (0.75 mm thick x 4.0 mm high) will also be added to prevent canine rotation.

This is the elastic chain configuration (on a different patient) that will be used with the posterior TAD for anterior anchorage control during molar distalization in refinement. The composite attachment on the canine is necessary to help prevent the tooth from rotating distally.

**Treatment Notes**

All 4 first bicuspids were extracted after the set-up was approved, and the attachments were bonded after aligner #1 was worn but before aligner #2 was given. Invisalign G6 SmartForce attachments were used on the lower right cuspid and as a result, the lower right cuspid is tracking very well without any excessive distal crown tip. The progress panoramic radiograph taken after 18 months of treatment also shows parallel molar and bicuspid roots.
Case #3

CLINICAL INSIGHT – In bimaxillary protrusion cases where A-P correction is needed along with facial profile changes, bonded power arms can be used and are very convenient to incorporate into Invisalign treatment.

Patient’s chief concern: Crowding.

Diagnosis

- 28 year-old female
- Right side: Molar Class 1, Canine Class 2 (mild)
- Left side: Molar Class 3, Canine Class 3 (mild)
- Upper arch: Mild crowding
- Lower arch: Severe crowding
- Key cephalometric values:

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<td>98˚</td>
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Initial Images

Treatment Description

Treatment plan: Extract all four permanent first bicuspids. In the ClinCheck set-up, add power arms to the canines and second bicuspids, and use the newly redesigned pontic spaces for maximum aligner engagement in the bicuspid extraction areas. The reason for using power arms here is because elastics for A-P control are needed, but elastic hooks cut into the aligner and the new attachments for controlling root tip cannot be placed on the same tooth at the same time.

The shapes on the canines and second bicuspids are where the power arms will be bonded to the teeth with the attachment template.
Power arms were conveniently integrated into the treatment plan using a bonding template that is included with the aligners. Power arm hooks (Universal crimpable hooks 9122-070, Shinye Company, China) were attached to the teeth with light-cured flowable resin (Filtek™ Z350XT, 3M ESPE, USA) and simultaneously bonded with adhesive (Adper™ Single Bond, 3M ESPE, USA).

The aligner fit after 8 months of treatment. Aligners were worn over the bonded power arms and elastics used (1/8” 2 oz., changed every 24 hours) to counteract the mesial crown tipping forces generated during extraction space closure.

Treatment progress images (after 20 months of treatment, 50 stages, 10 days of wear for each aligner):

Treatment Notes
A progress panoramic radiograph taken after 20 months of treatment shows good root parallelism of the canines and posterior teeth. Buttons were bonded to the lower first molars for Class 2 elastics to the upper canine power arms. The lower aligners were trimmed to accommodate the buttons using a high-speed handpiece and flame-shaped bur. Class 3 elastics on the left side may be needed later, in order to help center the midline. If additional aligners are needed to refine the case, the aligners can be pre-trimmed to fit around the bonded buttons.
Case #4

CLINICAL INSIGHT: TADs and bonded buttons are very convenient to incorporate into Invisalign aligner treatments where absolute anchorage control is needed in order to maximize anterior retraction into the bicuspid extraction space.

Patient’s chief concern: crowding and protrusion

Diagnosis

- 27 year old female
- Right: Molar Class 1, Cuspid Class 2 (moderate)
- Left: Molar Class 1, Cuspid Class 2 (moderate)
- Upper arch: Mild crowding
- Lower arch: Moderate crowding
- 4.7 is significantly lingually tipped
- Key cephalometric values:

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<td>Nasolabial angle</td>
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Initial Images

Treatment Description

Treatment Plan: Extraction of all four permanent first bicuspids after the aligners are received, in order to maximize patient esthetics. Bond power arms to the canines and second bicuspids with an attachment template, and connect the power arms with elastics during anterior retraction, in order to minimize crown tipping into the extraction space. Place TADs (VectorTAS™, Ormco, USA) bilaterally between U5 and U6 for maximum posterior anchorage, and tie a ligature wire between the TAD and a bonded button on U6 to prevent mesialization. Pre-trim the upper aligners to accommodate the bonded buttons on the molars. Use pontics shaped for maximum aligner engagement of the teeth during space closure.

Image of the aligner trim line (in blue) to accommodate the bonded button that will be tied to the TAD with ligature wire. The gray-colored teeth are the redesigned pontic spaces, each having mesial and distal separations which allow for maximum aligner engagement to the adjacent teeth.
CLINICAL TIPS & TECHNIQUES

Treatment progress images (after 21 months, 82 stages, 1 week of wear for each aligner):

Treatment Notes

The lower aligners were trimmed to fit around the bonded buttons with a high-speed handpiece and flame-shaped bur, since the buttons were added after the aligners were received. Slight mesial tipping of the U6s was observed during extraction space closure because the ligature wire connecting the TAD to the button was not rigid enough. The first molar angulation might have been better controlled by adding buttons to the U5s also, and ligating U5, U6, and the TAD together in the shape of a triangle.

Since the Invisalign G6 SmartForce attachments for controlling posterior angulation cannot be used on the teeth at the same time as bonded buttons, the current plan is to refine the case with additional aligners and undo the upper first molar tipping by distalizing them. Elastics between the TADs and the U3 power arms will maximize the posterior distalization while minimizing the anterior advancement. In the lower arch, additional leveling of the curve of Spee is planned along with lower anterior IPR if needed, to establish normal overbite and overjet. A progress panoramic radiograph is currently not possible due to pregnancy of the patient.

DISCUSSION

The advantages of using Invisalign aligners for the treatment of bimaxillary dental protrusion extend well beyond the basic benefits of nearly invisible aligner treatment where patients can enjoy the relative comfort and convenience of being able to remove the appliances to eat, brush, and floss normally throughout treatment.

So far, the following positive outcomes have been observed in the bimaxillary dental protrusion patients treated with Invisalign aligners and first bicuspid extraction:

- Improvement in the patient’s facial profile. The actual amount of incisal inclination and nasolabial angle change will be measured using cephalometric measurements once the treatments are completed.
- Root parallelism of molars and bicusps verified with progress panoramic radiographs, except in one patient where radiographic films could not be taken due to pregnancy.
- Successful canine tip control when Invisalign G6 SmartForce attachments were used.
- Good oral hygiene present throughout treatment.
- Convenient integration of common orthodontic auxiliaries such as elastics, power arms, TADs, and bonded buttons.

Additional learnings from these treatments include the following:

- The bicuspid extraction procedure should be performed after the initial aligner has been delivered. Tooth-colored material can be placed inside the pontic spaces of the aligner to hide any visible extraction sites, even though this was not an aesthetic concern for any of the patients presented.
- The sagittal bite relationship needs to be constantly monitored throughout treatment and A-P elastics incorporated into the treatment as needed.
- Power arms should be considered when both root tip control and A-P control are needed simultaneously, since SmartForce optimized attachments cannot be used on the same tooth where a precision-cut elastic hook or button cut-out is located.
- In areas where optimized attachments are present, avoid creating tension with elastics that might disengage parts of the aligner from the teeth and alter the intended force profile.
• Elastic chain used to connect TADs to buttons bonded on teeth tends to rotate the anchor tooth, especially when the aligners are not being worn during eating and brushing. This can lead to aligner fit problems. Only using elastics when the aligners are being worn helps to avoid this problem, but this also requires good patient cooperation with elastics wear. Another solution is to only use elastic chain if a long rectangular attachment is also added to the anchor tooth to prevent rotation.

• When using TADs as absolute anchors, the TAD should be ligated to one tooth mesial and to one tooth distal of the TAD, in order to prevent the posterior teeth from tipping mesially during anterior retraction. The ligature wire should be twisted tightly to create a triangle, with the TAD and the buttons on the anchor teeth forming the three corners.

• Increased overbite during retraction of the incisors may interfere with the mandible’s ability to move forward during treatment. However, Align Technology has recently updated the Invisalign G6 features to include anterior activations to better control upper incisor inclination and vertical dimension during anterior retraction.

Aligner activations in the anterior region is a new feature that was added after the cases presented in this paper were started. This technology is designed to improve incisor inclination and vertical control during extraction space closure. Image provided by Align Technology, Inc.

CONCLUSIONS

The Invisalign system offers several unique features for the treatment of bimaxillary dental protrusion with first bicuspid extraction and maximum anchorage.

1. The Invisalign G6 SmartForce attachments for the posterior teeth are designed to minimize anchorage loss during anterior retraction and help avoid unwanted mesial tipping.

2. The Invisalign G6 SmartForce attachments for the cuspids are designed to minimize unwanted distal crown tip during retraction.

3. The redesigned Invisalign pontic maximizes the aligner’s engagement to the adjacent teeth and also allows tooth-colored material to be added to the aligner for improved esthetics during extraction space closure.

4. Precision-cut aligner trim options allow for easy and accurate placement of bonded buttons. These bonded buttons can be connected to TADs for absolute anchorage control, if needed.

5. The option to place power arms with a new bonding template makes adding these auxiliaries to the treatment plan much more convenient.

The availability of these features provides the doctor with much greater flexibility than before, along with many more options for treating complex malocclusions with Invisalign aligners. However, some of these new features cannot be used at the same time as other feathers, and each feature has specific advantages and disadvantages, so careful treatment planning is needed with respect to the timing of when to incorporate each feature selected. This is especially important given that bicuspid extraction treatments with aligners tend to be longer treatments to begin with. Careful planning with regard to the selection and timing of each feature will help avoid treatment inefficiency and patient burnout, and ensure consistently good orthodontic treatment outcomes.

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