

# Esthetic Orthodontic Treatment Using the Invisalign Appliance for Moderate to Complex Malocclusions

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**Abstract:** In this report, three patients were treated with a new treatment protocol for Invisalign to demonstrate that a variety of complex malocclusions can be successfully treated using this protocol, including correction of moderate crowding, correction of moderate Class II division 1, and deep overbite. Previous studies of Invisalign showed significant limitations for more complex orthodontic treatment, although a few recent case reports have shown successfully completed moderate to difficult orthodontic malocclusions. One reason for the discrepancy is that the earlier studies were done during the first four years of the appliance development (now ten years of clinical use), when significant problems existed with accomplishing bodily movement, torquing of roots, extrusions, and rotations of premolars and canines. The new protocol included new methods for anterior/posterior corrections, showing on the computer the effect of elastics for Class II treatment simulated as a one-stage anterior/posterior movement at the end of treatment. Staging for interproximal reduction (IPR) is now automatically staged when there is better access to interproximal contacts to avoid IPR where significant overlap between teeth is present to avoid performing IPR on surfaces that may be damaged by instruments such as burs, strips, and disks when cut on a sharp angle. Staging for tooth movements is now also done to enable combination movements to occur simultaneously for each tooth with the tooth that needs to move the most (the lead tooth) determining the minimum number of stages required. All other teeth move at a slower rate than the lead tooth throughout the duration of treatment. Attachments are now placed in the middle of the crown automatically for rotation and automatically sized in proportion to the clinical crown. Use of 1 mm thick (buccal-lingual dimension) horizontal beveled rectangular attachments is standard on premolars for retention of aligners during intrusive movements, such as leveling the lower curve of Spee in deep overbite for extrusions and for control of the tooth long axis during torquing movements. Staging of tooth movements now track linear and rotational velocities of teeth separately with the number of treatment stages determined by the lead tooth based on its rotational or linear maximum velocities at no more than two degrees of rotation per stage. Simultaneous movements are done for all teeth providing visible space (approximately 0.05 mm) between teeth during movements past other teeth using expansion instead of IPR as a primary way to increase space available for correction of crowding.

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Since the introduction of Invisalign treatment,<sup>1,2</sup> controversy has existed over whether moderate to difficult orthodontic treatment can be routinely accomplished with the Invisalign system.<sup>3-19</sup> Several earlier studies<sup>12,17-19</sup> showed significant limitations in treatment for these complex patients, while more recent case reports<sup>11,13-15</sup> have shown successfully completed moderate to difficult orthodontic malocclusions. One reason for the discrepancy is that the earlier studies were done during the first four years of the appliance development, when significant problems existed with accomplishing bodily movement, torquing of roots, extrusions, and rotations of premolars and canines. Reference will be made only to the Invisalign system, which was used exclusively for these patients.

## Evaluating the Invisalign System

There have been two longitudinal clinical trials<sup>17-19</sup> and one cross-sectional study<sup>12</sup> that evaluated the Invisalign appliance. These first studies demonstrated that the use of this appliance is successful for several types of tooth movement, such as tipping, rotations of incisors, and closure of naturally occurring space. More difficult movements, such as bodily movement for extraction space closure, were less successful. One of these studies<sup>19</sup> also showed intrusion was predictable using clear aligners. However, these studies were done during the first four years of appliance development. The first of these studies<sup>17,18</sup>

was a study evaluating different appliance materials that are no longer used (soft versus hard material) and whether a one- or two-week interval before the patient progressed to the next aligner was more effective. For the past eight years, the protocol for changing clear aligners has been two weeks of wear for each appliance. Invisalign appliances are now manufactured using a material with intermediate stiffness compared to the materials used in that study.

Both of the longitudinal studies showed statistically significant reductions of plaque and gingivitis during treatment. Numerous studies have shown that orthodontic treatment using fixed appliances, even when a highly structured preventive program is followed to minimize the effects on periodontal tissues and enamel,<sup>20,21</sup> frequently increases plaque and gingivitis. One cross-sectional study<sup>12</sup> compared the first fifty consecutive clear aligner cases that were done by an orthodontist against fifty matched cases done with fixed appliances. Using the American Board of Orthodontics grading criteria, researchers found that fixed appliance users generally finished treatment with better results than those who used clear aligners. The orthodontist who treated the patients was an American Board of Orthodontics Diplomate with more than twenty-five years of experience with fixed appliances. The patients in this study were treated between 1999 and 2002, when clear aligners were relatively new and had the limitations previously noted.

One of the more commonly encountered types of patients who request Invisalign treatment are those who have previously received orthodontic treatment using fixed appliances and do not want fixed appliances for their present orthodontic treatment.<sup>11</sup> Esthetic concerns during follow-up orthodontic treatment may be a significant factor, with many patients not wanting to show metal or partially clear fixed appliances with arch wires when they smile.

A recent article by Spears<sup>22</sup> showed that patients who require minor restorative dentistry and/or bleaching can be good candidates for orthodontic treatment to solve their esthetic needs. The author further concluded that these patients will be more likely to accept orthodontics with less invasive restorative dentistry than treatment with no orthodontics and extensive full coronal restorations. Another group of patients who want Invisalign are teenagers who wish to improve their esthetics, but are not interested in having the appearance of fixed appliances.<sup>11</sup> Patients

with short roots may also be good candidates for clear aligners. A recent study has shown no measurable root resorption in a longitudinal study of 100 consecutive Invisalign patients (Wheeler T, in preparation). However, this finding may have been because the patients were in treatment for a shorter time than in the studies of fixed appliance patients. This Invisalign finding is in contrast to findings with fixed appliances, which generally show an average of 10 percent of patients having clinically significant root resorption of 3 mm or more.<sup>23,24</sup>

An interesting finding with the use of the clear aligners has been reported with patients who have a mild anterior open bite.<sup>11</sup> In these patients, the bite may close slightly during treatment because of the intrusive effect on the posterior teeth from the increased interocclusal distance from the presence of the double thickness of appliance materials.<sup>25</sup> This partially closes the bite by providing an intrusive force on the posterior teeth with the patient's own natural bite force, according to another report.<sup>26</sup> This is in contrast with treatment for a patient with a similar open bite malocclusion, in which fixed appliances may extrude the teeth during treatment and can lead to an increase in the amount of open bite,<sup>27,28</sup> especially when interarch elastics are used to extrude the anterior teeth.

Patients who have excessive wear on their teeth from grinding or bruxing may also be good candidates for aligner treatment because the appliances serve as a thin night guard to prevent occlusal wear. After treatment, clear retainers are generally worn indefinitely at night for retention. This can potentially lessen the effects of nocturnal clenching, grinding, or bruxism over time. A recent study by Nedwed and Meithke<sup>29</sup> and another study by Miller et al.<sup>30</sup> found that, even among patients who have a history of parafunctional habits and pain, clear aligner treatment actually decreases myofascial discomfort from parafunctional habits such as clenching, grinding, and bruxing during treatment. This may be attributed to the potential double splint effect of the appliances that disarticulate the teeth with smooth plastic surfaces.

In a recent study<sup>30</sup> on the discomfort levels of clear aligner treatment compared to fixed appliances, it was determined that aligners cause much less patient discomfort compared to fixed appliances for mucosal irritation, soreness of the teeth, and several other areas of potential discomfort usually experienced by patients during orthodontic treatment

with fixed appliances. Another potential advantage of clear aligner treatment is found in patients with extensive porcelain, gold, or highly restored mouths. When fixed appliances are bonded and debonded, metal or porcelain surfaces of teeth are usually more difficult for retention of appliances during treatment. There is also the potential of damaging the surfaces of porcelain, gold, or other metal restorations at the time of debonding.

Advantages of using clear aligner treatment may also include correction of deep overbite<sup>3,9</sup> because of the more predictable nature of orthodontic intrusion mechanics and disclusion of the teeth, which eliminates problems encountered with fixed appliances from occlusal interferences.<sup>11</sup> Recently, it has been shown that anterior and posterior dental crossbites can be effectively treated with clear aligner treatment,<sup>11</sup> most likely due to the disclusion effect on the teeth using clear aligner treatment. However, crossbites that are skeletal in origin should be treated with orthopedic or surgical methods.

It has been shown that clear aligner treatment in combination with fixed appliances placed at the time of surgery are an effective form of treatment with difficult orthognathic surgery patients involving surgical movements in all three planes of space.<sup>13</sup>

Another recently published<sup>31-34</sup> advantage of clear aligner treatment is the use of a computer plan as a virtual diagnostic setup. When viewing this plan, a decision can be made on the appropriate strategy to treat the patient, which may involve distalization of molars, interarch elastics, extraction, interproximal reduction (IPR), expansion, or some combination of these. The initial computer setup can provide a therapeutic diagnostic setup. Other advantages include evaluating anchorage with the superimposition tool or surgical (interarch movement) simulation tools. Additional benefits cited in these reports include providing a consultation device to show treatment limits to patients; a communication tool to email the abbreviated version of the virtual treatment to patients and referring doctors; and verifying that the aligner is tracking. Other unique benefits of this software are the ability to evaluate all of the stages throughout treatment to determine the biomechanical and biological feasibility of treatment and analyzing the pathways through which the teeth move during simulated treatment.<sup>35,36</sup>

## Recent Invisalign Protocol Improvements

Recently, numerous improvements have been introduced to the protocol for use of the Invisalign system.<sup>36</sup> These changes fall into the categories of anterior/posterior corrections, staging for interproximal reduction, staging for tooth movements, attachments, and staging of tooth movements.

### Anterior/Posterior (A/P) Corrections

- Setups are designed to allow easier visualization of the anticipated treatment goal when incorporating interarch elastics in the treatment plan. Individual tooth movements required to align teeth are set up to project the effect of this bite correction using buttons and elastics.
- Elastic wear is recommended from the start of treatment, continuing until the desired A/P correction has been achieved.
- Setups will default to display A/P bite corrections incorporating the effects of interarch elastics.
- The effect of elastics is simulated as a one-stage anterior-posterior movement at the end of treatment, which enables verification of the final arch coordination and occlusion.
- Fewer aligners are required when simultaneous staging is employed along with use of elastics as compared with distalization.
- Distalization staging may be requested in the special instructions of the treatment form or during ClinCheck Review, but anchorage support with interarch elastics is still highly recommended. (Note that, if this method is chosen, Class II elastics may still be needed for anchorage support, and the number of aligners may increase significantly.)

### Staging for Interproximal Reduction (IPR)

- The timing of IPR is automatically staged when there is better access to interproximal contacts.
- IPR will be staged when there is not a significant overlap between teeth to avoid performing IPR on surfaces that may be damaged by instruments such as burs, strips, and disks cutting on a sharp angle.

- Saving necessary IPR may be needed for Bolton's discrepancies and other tooth-size issues until the teeth are aligned to avoid removing enamel on an angle.

## Staging for Tooth Movements

- Cases are staged to enable combination movements to occur simultaneously for each tooth.
- The tooth that needs to move the most (lead tooth) will determine the minimum number of stages required. All other teeth will move at a slower rate than the lead tooth.
- All teeth move throughout the duration of treatment.

## Attachments

- Attachments are now placed in the middle of the crown vs. 2 mm from the gingival margin.
- There are reduced rotational and extrusion values to trigger automated attachment placement.
- Rotational attachments are automatically sized in proportion to the clinical crown.
- Attachments are placed for smaller rotations.
- Longer clinical crowns will automatically get a longer rotational attachment.
- One mm thick vertical rectangular attachments are used for rotations of round teeth or canines as well as translation of teeth adjacent to an extraction site.
- Use of 1 mm thick (buccal-lingual dimension) horizontal beveled rectangular attachments is standard on premolars for retention of aligners during intrusive movements such as leveling the lower curve of Spee in deep overbite, for extrusions, and for control of the tooth long axis during torquing movements.

## Staging of Tooth Movements

- Linear and rotational velocities of teeth are tracked separately.
- The minimal number of treatment stages is determined via the lead tooth (tooth moving the most) based on its rotational or linear maximum velocity.
- Slower rotations are staged in treatment (choice of one or two degrees of rotation per stage).
- The clinical criteria for Express Treatments (ten stages or less) is being updated to ensure consistency

tency as the new rotational velocity improvements are implemented on all cases.

- Movements of all teeth are simultaneous. This is similar to the effect of light wire and low friction brackets for leveling and alignment in that all of the teeth are moving during the entire treatment. This has the advantage of creating the necessary space for movements and slowing down the velocity of all tooth movements except for movement on the tooth that takes the most stages to complete at a given velocity (the lead tooth).
- Visible space (approximately 0.05 mm) is provided between teeth during movements past other teeth.
- Expansion instead of IPR is used as a primary way to increase space available for correction of crowding.

## Case Presentations

All three cases presented here had noncontributory medical histories, no symptoms of temporomandibular dysfunction, and a strong desire not to have fixed appliances. No fixed appliances were used on any of the patients; however, all patients were told that fixed appliances may be necessary to complete treatment. All patients used clear retainers for full-time retention four to six months after treatment, followed by nighttime wear indefinitely.

### Patient 1

The first patient is a sixty-five-year-old female who began treatment with a mild Class I malocclusion and a chief complaint of "crowding" and "wants a beautiful smile." She had 4 mm of upper and lower crowding and many posterior restorations including an implant to replace the upper left first premolar.

Appendix 1 shows pre- and post-treatment facial and intraoral views, intraoral radiographs, and lateral cephalometric radiograph and analysis. The post-treatment views show the posterior occlusion was maintained with good alignment of the anterior teeth. Treatment time was eight months with one set of fifteen upper and lower aligners. Interproximal reduction was done on the upper incisors due to a Bolton discrepancy, which indicated excess mandibular space. Cephalometric evaluation shows tooth movement with almost no change in the skeletal relationship.



## Patient 2

The second patient is a fourteen-year-old female who began treatment with a chief complaint of “crowded teeth.” The occlusion was a mild Class II division 1 deep overbite and 5 to 6 mm of upper and lower crowding.

Appendix 2 shows facial and intraoral views, intraoral radiographs, and lateral cephalometric radiograph and analysis. Note the extremely short roots of the upper central incisors. The post-treatment intra- and extraoral views show a Class I occlusion with good alignment and no root resorption on these upper incisors. Cephalometric evaluation shows slight growth of the mandible during treatment that probably helped the anterior/posterior correction. Treatment time was thirteen months with one set of fourteen upper and twenty-four lower aligners used. Four-ounce Class II elastics were used during the thirteen-month treatment from clear buttons bonded from the upper first premolars to metal buttons bonded on the lower first molars. Aligners were cut back to provide space for the buttons. The cephalometric evaluation shows no opening of the mandibular plane angle in the superimposition, which reflects good vertical control of the tooth movement.

The two-year post-treatment photos show good stability of the corrected occlusion.

## Patient 3

The third patient is a sixteen-year-old female who began treatment with a chief complaint of “overbite.”

Appendix 3 shows facial and intraoral views, intraoral radiographs, and lateral cephalometric radiograph and analysis. The occlusion was a mild Class II division 1 subdivision right with moderate upper and mild lower crowding. The post-treatment views show a Class I occlusion with good alignment. Treatment time was fourteen months with one set of fourteen upper and twenty-four lower aligners used. No interproximal reduction was done. Four-ounce Class II elastics were also used by this patient during the thirteen-month treatment from a clear button bonded to the upper right first premolar to a metal button bonded to the lower first molar. Aligners were cut back to provide space for the buttons. The cephalometric evaluation shows no significant opening of the mandibular plane angle in the superimposition, which reflects good vertical control of the tooth movement.

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## Discussion

Patient compliance is a critical factor for success with clear aligner treatment. Treatment success depends almost completely on how compliant the patient is with wearing aligners for approximately twenty hours a day, seven days a week. Treatment time and ability to complete treatment vary considerably according to the degree of patient compliance. The three patients in this report were selected because they had good treatment outcomes, which meant they were highly compliant with wearing aligners.

It is important to point out that although this report shows good results are possible in moderate to difficult malocclusions, significant clinical experience with other orthodontic treatment methods, diagnosis, treatment planning, and biomechanics are required for successful treatment. These skills form the basis for reviewing the entire staging process using Invisalign’s ClinCheck software in order to achieve successful outcomes. This software offers a unique opportunity for the clinician to examine probable therapeutic outcomes for a specific diagnosis before treatment is started. In addition, the software allows the clinician to examine specific movements for all teeth in detail throughout the staging of sequential appliances before treatment is started. The advantage of this is that the clinician can determine the optimal biologic and biomechanical aspects and their incorporation into treatment.

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## Summary

In this report, patients were treated with Align Technology’s new best practices protocol. These three patients’ treatments demonstrate that a variety of complex malocclusions are able to be successfully treated using this protocol, including corrections of moderate crowding and malocclusions with moderate Class II division 1 and deep overbite. However, it is important to point out that studies are needed that test this new protocol to determine if the outcomes described in this report can be reliably repeated by other clinicians in comparable situations.

The change to this new protocol may enable some clinicians who used Invisalign in the first three years after release but then abandoned it because of initial shortcomings to achieve more predictable tooth movement. It is worth noting that all the patients’ treatments were completed with one series of aligners

or with only one case refinement and no midcourse corrections.

It is important that the doctor understand the entire staging process, using ClinCheck software to examine the details and pathways of all of the individual tooth movements for consecutive appliances before any treatment is started to determine the biologic and biomechanical feasibility of treatment.

Because it is still relatively early in the evolution of this appliance and most clinicians did not learn about clear aligner treatment in dental school or orthodontic training, clinicians who want to use clear aligners in their practice would benefit from taking standardized, sequential levels of education before using this approach. Clinicians should also gain significant clinical experience in the treatment of mild malocclusions before initiating treatment for more complex malocclusions.

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## APPENDIX 1

### Patient 1

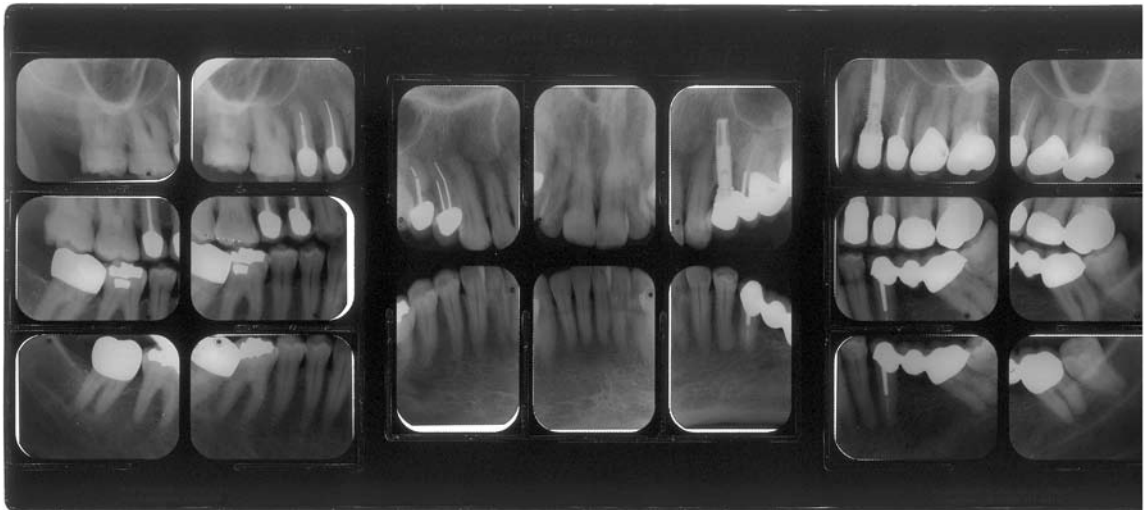
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#### Pre-treatment views





### Pre-treatment radiographs



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### Post-treatment views



### Post-treatment views and radiograph



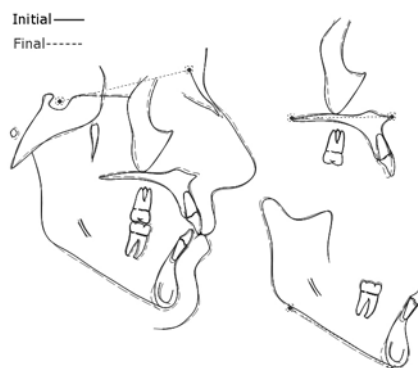
## Cephalometric analyses

Initial Cephalometric Analysis

Measures	Value	Norm
SNA	75	82
SNB	72	80
ANB	4	2
Wits Appraisal	1	0
FMA (MP-FH)	30	22
FMIA (L1-FH)	61	65
IMPA (L1-MP)	90	90
MP - SN	44	33
U1 - SN	94	102
U1 - NA (°/mm)	19 / 6	22 / 4
L1 - NB (°/mm)	26 / 7	25 / 4
IIA	132	130
Pog - NB	3	2

Final Cephalometric Analysis

Measures	Final	Initial	Norm
SNA	77	75	82
SNB	73	72	80
ANB	4	4	2
Wits Appraisal	0	1	0
FMA (MP-FH)	29	30	22
FMIA (L1-FH)	58	61	65
IMPA (L1-MP)	94	90	90
MP - SN	45	44	33
U1 - SN	89	94	102
U1 - NA (°/mm)	13 / 3	19 / 6	22 / 4
L1 - NB (°/mm)	30 / 8	26 / 7	25 / 4
IIA	132	132	130
Pog - NB	3	3	2



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## APPENDIX 2

### Patient 2

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#### Pre-treatment views



### Pre-treatment radiograph



### Post-treatment views





### Post-treatment views and radiograph



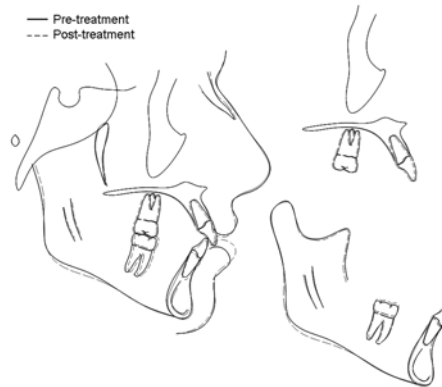
## Cephalometric analyses

Initial Cephalometric Analysis

Measures	Value	Norm
SNA	76	82
SNB	75	80
ANB	2	2
Wits Appraisal	1	0
FMA (MP-FH)	26	22
FMIA (L1-FH)	59	65
IMPA (L1-MP)	95	90
MP - SN	37	33
U1 - SN	105	102
U1 - NA (°/mm)	29 / 7	22 / 4
L1 - NB (°/mm)	27 / 5	25 / 4
IIA	123	130
Pog - NB	1	2

Final Cephalometric Analysis

Measures	Final	Initial	Norm
SNA	75	76	82
SNB	74	75	80
ANB	1	2	2
Wits Appraisal	0	1	0
FMA (MP-FH)	25	26	22
FMIA (L1-FH)	60	59	65
IMPA (L1-MP)	95	95	90
MP - SN	36	37	33
U1 - SN	105	105	102
U1 - NA (°/mm)	30 / 7	29 / 7	22 / 4
L1 - NB (°/mm)	25 / 5	27 / 5	25 / 4
IIA	124	123	130
Pog - NB	2	1	2



### Two-year post-treatment views



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## APPENDIX 3

### Patient 3

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#### Pre-treatment views





### Pre-treatment radiograph



### Post-treatment views





### Post-treatment views and radiograph



## Cephalometric analyses

Initial Cephalometric Analysis

Measures	Value	Norm
SNA	88	82
SNB	80	80
ANB	8	2
Wits Appraisal	4	0
FMA (MP-FH)	31	22
FMIA (L1-FH)	53	65
IMPA (L1-MP)	96	90
MP - SN	35	33
U1 - SN	99	102
U1 - NA (°/mm)	11 / -2	22 / 4
L1 - NB (°/mm)	31 / 7	25 / 4
IIA	130	130
Pog - NB	0	2

Final Cephalometric Analysis

Measures	Final	Initial	Norm
SNA	88	88	82
SNB	80	80	80
ANB	8	8	2
Wits Appraisal	4	4	0
FMA (MP-FH)	31	31	22
FMIA (L1-FH)	54	53	65
IMPA (L1-MP)	95	96	90
MP - SN	35	35	33
U1 - SN	98	99	102
U1 - NA (°/mm)	11 / -1	11 / -2	22 / 4
L1 - NB (°/mm)	30 / 7	31 / 7	25 / 4
IIA	132	130	130
Pog - NB	0	0	2

