Prediction of Soft Tissue Profile following Two-Jaw Surgery

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Abstract

The purposes of this study were to investigate the facial changes by two-jaw surgery for mandibular prognathism accompanying maxillary hypoplasia and skeletal open bite, and to design a regression model that predicts the soft tissue profile changes after two-jaw surgery. Fourteen cases diagnosed as mandibular prognathism accompanying maxillary hypoplasia and skeletal open bite at the Nihon University Hospital, School of Dentistry at Matsudo were studied. The surgical methods used were Le Fort type I osteotomy for the maxilla and sagittal split ramus osteotomy for the mandible. Angle measurements showed significant differences in SNA, ANB, FA, FD and MPA ($p < 0.01$), and significant difference in SNB ($p < 0.05$). In horizontal distances, PTV-L1, PTV-Id, PTV-B, PTV-Pog and PTV-Me changed significantly ($p < 0.01$). In vertical distances, a significant change in N-Me was observed ($p < 0.05$). In horizontal distances, significant changes were observed in PTV-Li and PTV-Spog ($p < 0.01$), and in PTV-St ($p < 0.05$). In vertical distances, significant changes in PTV-St and PTV-Li were observed ($p < 0.05$). No significant changes in cheek line were observed. For the horizontal lip and chin position, the multiple correlation coefficients R ranged from 0.89 to 0.95, and for the horizontal position of the cheek line, the multiple correlation coefficients R ranged from 0.65 to 0.84, indicating a high precision of the prediction equations obtained in this study. In conclusion, the result of this study indicates that the prediction equation for lips and chin has a high precision and can be applied to predict soft tissue profile in two-jaw surgery.

Keywords :

two-jaw surgery, soft tissue profile, prediction

Introduction

In patients with skeletal mandibular protrusion due to marked hyperplasia of the mandibular bone and skeletal maxillary retrusion due to hypoplasia of the maxillary bone (mandibular prognathism accompanying maxillary hypoplasia), surgical orthodontic treatment is conducted by a combination of maxillary advancement and mandibular setback (two-jaw surgery). In addition, in mandibular prognathism of the long face, as well as in severe skeletal open bite, two-jaw surgery is used to correct the gradient of occlusal plane. In these cases of severe jaw deformity, surgical orthodontic treatment not only improves occlusion, but may also improve the soft tissue profile (1, 2).

Therefore, the patient's expectation toward surgi-

cal orthodontic treatment is not only on the improvement of occlusion and mastication, but more on esthetic improvement of soft tissue profile. For that reason, predicting the changes of soft tissue profile as a result of the surgical orthodontic treatment before starting surgery is important also from the viewpoint of obtaining informed consent from the patient. Furthermore, this information probably also serves as an indication for the choice of surgical method.

Changes of the hard and soft tissues after surgical orthodontic treatment by mandibular setback surgery have been reported in many papers (3-5), but the morphological changes of soft tissue profile after surgical orthodontic treatment by two-jaw surgery or the sites of soft tissue changes caused by man-

dibular and maxillary displacement have not been studied adequately. The purposes of this study were to investigate the facial changes by two-jaw surgery for mandibular prognathism accompanying maxillary hypoplasia and skeletal open bite, and to design a regression model that predicts the soft tissue profile changes after two-jaw surgery.

Materials and Methods

Fourteen cases diagnosed as mandibular prognathism accompanying maxillary hypoplasia and skeletal open bite at the Nihon University Hospital, School of Dentistry at Matsudo were studied. Cases of cleft-lip and palate, genioplasty and marked facial asymmetry were excluded. The surgical methods used were Le Fort type I osteotomy for the maxilla and sagittal split ramus osteotomy (SSRO) for the mandible. All surgeries were performed by the same operator. Multi-bracket appliance was used for preoperative and postoperative orthodontic treatment.

The mean age of the subjects in the first medical

examination was 21.4 ± 4.8 years. Lateral cephalograms were taken before starting orthodontic treatment and after completion of orthodontic treatment (over 6 months after surgery).

Lateral cephalogram

Lateral cephalogram were taken in the upright position, with the Frankfort horizontal line (FHL) parallel to the floor and in habitual occlusal position (Fig. 1). To eliminate measurement errors, the author made the lateral cephalometric tracings and measurements, and confirmed the measurement points. The measurement points and reference lines of lateral cephalometric tracings are shown in Figs. 2 and 3.

1) Reference points of hard tissue

S: Sella turcica, N: Nasion, Or: Orbitale, Po: Porion, ANS: Anterior nasal spine, PNS: Posterior nasal spine, PT: Pterygoid point, Pog: Pogonion, Ba: Basion, Me: Menton, Ar: Articulare, A: Point A, B: Point B, U1: Incisal edge of upper central incisor, L1: Incisal edge of lower central incisor.

A

B

Fig. 1. Lateral cephalograms mandibular prognathism accompanying maxillary hypoplasia. A: pretreatment. B: posttreatment.

Fig. 2. Landmarks of lateral cephalogram.

N : Nasion, S : Sella, Or : Orbitare, Po : Porion, PT : PT point, ANS : Anterior Nasal spine, PNS : Posterior nasal spine, Ba : Basion, A : Point A, Pr : Prosthion, U1 : Incisal edge of upper central incisor, L1 : Incisal edge of lower central incisor, Id : Infradentale, B : Point B, Pog : Pogonion, Me : Menton, Sn : Subnasale, SnLs : Midpoint of Sn-Ls, Ls : Labrale superius, St : Stomion, Li : Labrale inferius, SPog : Soft tissue Pogonion, FHL : Frankfort horizontal line (Horizontal reference line), PTV : the line perpendicular to the Frankfort horizontal line and passing PT point (Vertical reference line).

Fig. 3. Landmarks of cheek line.

C1 : intersection point of perpendicular to PTV and cheek line under 1 cm from FHL.
C2 : intersection point of perpendicular to PTV and cheek line under 2 cm from FHL.
C3 : intersection point of perpendicular to PTV and cheek line under 3 cm from FHL.
C4 : intersection point of perpendicular to PTV and cheek line under 4 cm from FHL.

2) Reference points of soft tissue (6)

Sn : Subnasale, SnLs : Middle point of Sn to Ls, Ls : Labrale superius, St : Stomion, Li : Labrale inferius, Spog : Soft tissue Pogonion, C1 : cheek line 1 (intersection point of perpendicular to PTV and

cheek line under 1 cm from FHL), C2 : cheek line 2 (intersection point of perpendicular to PTV and cheek line under 2 cm from FHL), C3 : cheek line 3 (intersection point of perpendicular to PTV and cheek line under 3 cm from FHL), C4 : cheek line 4 (intersection point of perpendicular to PTV and cheek line under 4 cm from FHL).

Measurement variables

The angle measurements of facial morphology were conducted according to the methods of Tweed (7) and Ricketts (8). The angle measurements of facial morphology are shown in Fig. 4. The horizontal and the vertical distances of the maxilla and mandible were measured according to the methods of Higashi et al (9) and Saitoh (10). The horizontal and vertical distances of the maxilla and mandible are shown in Figs. 5 and 6. The horizontal and vertical distances of the soft tissue profile were measured making reference to the methods of Koiso et al (11). The horizontal and vertical distances of the lip and

Fig. 4. Angular measurements of facial morphology.

- (1) SNA
- (2) SNB
- (3) ANB
- (4) Facial axis (FA)
- (5) Facial depth (FD)
- (6) Mandibular plane angle (MPA)
- (7) Lower facial height (LFH)
- (8) Total facial height (TFH)
- (9) Mandibular arc
- (10) FH to palatal

Fig. 5. Linear measurements of maxilla and mandible (horizontal).

- (1) PTV-ANS: the distance from PTV to ANS on the line perpendicular to PTV.
- (2) PTV-A: the distance from PTV to A on the line perpendicular to PTV.
- (3) PTV-Pr: the distance from PTV to Pr on the line perpendicular to PTV.
- (4) PTV-U1: the distance from PTV to U1 on the line perpendicular to PTV.
- (5) PTV-L1: the distance from PTV to L1 on the line perpendicular to PTV.
- (6) PTV-Id: the distance from PTV to Id on the line perpendicular to PTV.
- (7) PTV-B: the distance from PTV to B on the line perpendicular to PTV.
- (8) PTV-Pog: the distance from PTV to Pog on the line perpendicular to PTV.
- (9) PTV-Me: the distance from PTV to Me on the line perpendicular to PTV.

chin soft tissues are shown in Figs. 7 and 8, and the horizontal distance of the cheek line in Fig. 9.

Statistical analysis

The mean and standard deviation (SD) were estimated for each of the cephalometric variables, and the differences between pretreatment variables and posttreatment variables were analyzed by paired *t*-test. A multiple regression analysis was conducted to estimate how surgical orthodontic treatment by two-jaw surgery resulted in changes of soft tissue profile. The multiple regression analysis was conducted by a stepwise method using soft tissue measurements as dependent variables and the maxillary and mandibular measurements as independent variables (12).

Fig. 6. Linear measurements of maxilla and mandible (vertical).

- (1) N-ANS: the distance from N to ANS on the line perpendicular to FHL.
- (2) N-Me: the distance from N to Me on the line perpendicular to FHL.
- (3) ANS-Me: the distance from ANS to Me on the line perpendicular to FHL.

Fig. 7. Linear measurements of lip and chin (horizontal).

- (1) PTV-Sn: the distance from PTV to Sn on the line perpendicular to PTV.
- (2) PTV-SnLs: the distance from PTV to SnLs on the line perpendicular to PTV.
- (3) FH-Ls: PTV-Ls the distance from PTV to Ls on the line perpendicular to PTV.
- (4) PTV-St: the distance from PTV to St on the line perpendicular to PTV.
- (5) PTV-Li: the distance from PTV to Li on the line perpendicular to PTV.
- (6) PTV-SPog: the distance from Spog to St on the line perpendicular to PTV.

Fig. 8. Linear measurements of lip and chin (vertical).

- (1) FHL-Sn: the distance from FHL to Sn on the line perpendicular to FHL.
- (2) FHL-SnLs: the distance from FHL to SnLs on the line perpendicular to FHL.
- (3) FHL-Ls: the distance from FHL to Ls on the line perpendicular to FHL.
- (4) FHL-St: the distance from FHL to St on the line perpendicular to FHL.
- (5) FHL-Li: the distance from FHL to Li on the line perpendicular to FHL.
- (6) FHL-Spog: the distance from FHL to SPog on the line perpendicular to FHL.

Results

Changes of hard tissue

The means and SDs for hard tissue variables at

Fig. 9. Linear measurements of cheek line.

- (1) PTV-C1: the distance from PTV to C1 on the line perpendicular to PTV.
- (2) PTV-C2: the distance from PTV to C2 on the line perpendicular to PTV.
- (3) PTV-C3: the distance from PTV to C3 on the line perpendicular to PTV.
- (4) PTV-C4: the distance from PTV to C4 on the line Perpendicular to PTV.

both the pretreatment and posttreatment stages and the differences between these stages are presented in Tables 1 and 2. Angle measurements showed significant differences in SNA, ANB, FA, FD and MPA ($p < 0.01$), and significant difference in SNB ($p < 0.05$). In horizontal distances, PTV-L1, PTV-Id, PTV-B, PTV-Pog and PTV-Me changed significantly ($p < 0.01$). In vertical distances, a significant change in N-Me was observed ($p < 0.05$).

Table 1. Angular measurements of hard tissue.

(degree)

	Pretreatment		Posttreatment		Differences		Paired <i>t</i> -test
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
SNA	84.3	4.9	87.4	6.5	3.2	3.2	**
SNB	87.9	7.0	84.9	6.5	-3.0	4.5	*
ANB	-3.7	3.9	2.5	3.5	6.2	5.4	**
FA	90.1	5.4	88.0	5.0	-2.1	2.6	**
FD	93.4	4.7	89.8	5.0	-3.6	3.7	**
MPA	29.8	8.3	32.4	7.8	2.6	3.1	**
LFH	50.3	6.0	52.2	4.9	1.9	4.1	N.S.
TFH	64.5	8.3	66.3	6.3	1.9	4.2	N.S.
MA	27.1	9.1	29.4	9.5	2.3	5.7	N.S.
FH to palatal plane	3.4	2.4	4.0	3.1	0.6	3.6	N.S.

N.S.: not significant

*: $p < 0.05$, **: $p < 0.01$

Table 2. Linear measurements of hard tissue. (mm)

	Pretreatment		Posttreatment		Differences		Paired <i>t</i> -test
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
<Horizontal>							
PTV-ANS	58.9	3.3	59.2	5.8	0.2	3.8	N.S.
PTV-A	53.9	3.8	54.9	6.0	1.1	3.9	N.S.
PTV-Pr	57.4	4.5	58.0	6.9	0.6	4.7	N.S.
PTV-U1	60.4	5.6	61.2	8.4	0.8	5.6	N.S.
PTV-L1	64.4	6.6	58.2	8.4	-6.2	4.7	**
PTV-Id	63.6	6.9	53.4	8.4	-10.1	5.7	**
PTV-B	59.5	9.2	50.6	9.7	-8.9	6.1	**
PTV-Pog	61.5	10.3	53.0	10.4	-8.5	6.0	**
PTV-Me	54.7	10.6	45.9	10.6	-8.8	6.1	**
<Vertical>							
N-ANS	60.8	2.9	60.0	2.7	-0.8	2.3	N.S.
N-Me	138.1	8.9	135.1	8.2	-3.0	4.4	*
ANS-Me	77.3	7.0	75.1	8.2	-2.1	4.7	N.S.

N.S.: not significant

*: $p < 0.05$, **: $p < 0.01$ *Changes of soft tissue*

The means and SDs for soft tissue variables at both the pretreatment and posttreatment stages and the differences between these stages are presented in Table 3. In horizontal distances, significant changes

were observed in PTV-Li and PTV-Spog ($p < 0.01$), and in PTV-St ($p < 0.05$). In vertical distances, significant changes in PTV-St and PTV-Li were observed ($p < 0.05$).

Table 3. Linear measurements of soft tissue. (mm)

	Pretreatment		Posttreatment		Differences		Paired <i>t</i> -test
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
<Horizontal>							
PTV-Sn	70.7	4.4	71.5	6.1	0.7	3.5	N.S.
PTV-SnLs	72.2	4.9	72.5	7.4	0.4	5.3	N.S.
PTV-Ls	77.9	5.4	77.5	6.8	-0.3	4.2	N.S.
PTV-St	72.3	5.8	68.6	8.2	-3.7	5.5	*
PTV-Li	79.9	7.0	73.8	8.5	-6.1	5.4	**
PTV-SPog	74.1	11.2	65.8	9.8	-8.2	5.7	**
<Vertical>							
FHL-Sn	34.3	3.8	35.5	4.9	1.2	4.2	N.S.
FHL-SnLs	43.1	4.5	44.3	4.4	1.2	3.7	N.S.
FHL-Ls	51.9	5.6	53.8	4.9	1.9	3.4	N.S.
FHL-St	58.8	6.0	60.9	5.1	2.1	3.4	*
FHL-Li	67.7	7.1	71.5	7.0	3.8	5.6	*
FHL-SPog	101.5	9.3	100.0	8.3	-1.6	5.8	N.S.

N.S.: not significant

*: $p < 0.05$, **: $p < 0.01$

Changes of cheek line

The means and SDs for cheek line at both the pretreatment and posttreatment stages and the differences between these stages are presented in Table 4. No significant changes in cheek line were observed.

Multiple regression analysis

Table 5 shows the multiple regression equations obtained from stepwise multiple regression analysis using horizontal lip measurements as dependent variables and facial hard tissue measurements as independent variables, and the multiple correlation coefficients. The multiple correlation coefficients R ranged from 0.89 to 0.95.

Table 6 shows the multiple regression equations and the multiple correlation coefficients obtained from stepwise multiple regression analysis using horizontal cheek line measurements as dependent variables and facial hard tissue measurements as independent variables. The multiple correlation coefficients R ranged from 0.65 to 0.84.

Discussion

In the characteristic of Japanese Mandibular prognathism, patients with mandibular hyperplasia are commonly observed (13). Therefore, for surgical orthodontic treatments in Japan, there are many reports on mandibular setback alone (14-16) but only few reports on maxillary advancement. In cases of

Table 4. Linear measurements of cheek line. (mm)

	Pretreatment		Posttreatment		Differences		Paired <i>t-test</i>
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
PTV-C1	58.5	3.9	59.2	5.7	0.6	4.7	N.S.
PTV-C2	59.9	4.1	60.3	5.1	0.4	5.3	N.S.
PTV-C3	61.0	4.2	60.9	5.2	-0.1	2.9	N.S.
PTV-C4	61.5	4.9	60.1	5.9	-1.4	3.8	N.S.

N.S. : not significant

* : $p < 0.05$, ** : $p < 0.01$

Table 5. Multiple regression analysis of horizontal variables of soft tissue.

Dependent variables	Multiple regression model	R	R ²
PTV-Sn	$0.49(\text{PTV-L1}) + 0.58(\text{PTV-Pr}) + [-0.50(\text{PTV-ANS})] + 3.52$	0.89	0.79
PTV-SnLs	$0.45(\text{PTV-U1}) + 0.55(\text{PTV-Pr}) - 0.32$	0.95	0.89
PTV-Ls	$0.31(\text{PTV-B}) + 0.93(\text{PTV-Pr}) + [-0.72(\text{PTV-A})] + 2.37$	0.90	0.82
PTV-St	$0.72(\text{PTV-L1}) + 0.92(\text{PTV-Pr}) + [-0.59(\text{PTV-A})] + 0.84$	0.95	0.90
PTV-Li	$0.69(\text{PTV-Pr}) + 0.32(\text{PTV-B}) - 3.92$	0.92	0.85
PTV-SPog	$1.80(\text{PTV-B}) + [-2.00(\text{PTV-L1}) + 0.58(\text{PTV-Pr}) - 5.47$	0.92	0.85

Table 6. Multiple regression analysis of horizontal variables of cheek line.

Dependent variables	Multiple regression model	R	R ²
PTV-C1	$0.78(\text{PTV-B}) + [-0.47(\text{PTV-Pog})] + 2.81$	0.84	0.71
PTV-C2	$0.58(\text{PTV-Pog}) + 5.33$	0.65	0.42
PTV-C3	$0.50(\text{PTV-L1}) + 2.96$	0.82	0.67
PTV-C4	$0.80(\text{PTV-L1}) + [-0.28(\text{PTV-Id})] + 1.18$	0.80	0.64

skeletal mandibular prognathism accompanying maxillary hypoplasia, Le Fort type I osteotomy is the widely used surgical method to advance the maxilla (17). The Le Fort I downfracture technique was designed by Bell (18), Epker and Wolford (19). For mandibular setback, SSRO is widely used. This technique was designed by Trauner and Obwegeser (20). The advantage of this method is that high stability can be obtained after surgery, because the mandible can be accessed from inside the oral cavity, a larger bone cut surfaces can be obtained, and osteotomy can protect the mandibular canal from the injury. Surgical orthodontic treatment is generally conducted at an age after the completion of jaw and facial morphology development. In this study, the pretreatment age was 21.4 ± 4.8 years, and the bone age of the patients were investigated. Therefore, growth is not associated with the changes of soft tissue profile (21, 22).

SNA changed significantly after surgery, the distance of FHL to palatal plane did not change significantly. These findings indicate that while the maxilla is advanced, there were little vertical changes including superior rotation and/or inferior rotation of the maxilla.

On the other hand, SNB, FA and FD were reduced significantly, and PTV-Id, PTV-B and PTV-Me also became significantly smaller. In addition, N-Me decreased significantly, while MPA increased significantly. These findings indicate that by two-jaw surgery, the mandible is displaced posteriorly while it also rotates clockwise, and the facial height is shortened. Furthermore, PTV-L1 was decreased significantly, showing that the mandibular anterior teeth are also displaced posteriorly accompanying setback and inferior rotation of the mandible. In SSRO, the anterior margin of the mandibular ramus is opened from the oral cavity and osteotomy of the mandible is made anteriorly from the gonion. For this reason, there were no effects on the measurements of the mandibular ramus including LFH, TFH and MA (20).

PTV-Li and PTV-St were significantly decreased by two-jaw surgery. PTV-Li and PTV-St are reported to be affected by the position of the mandibular

anterior teeth (23). In this study, accompanying displacement of the mandible, the mandibular anterior teeth were displaced posteriorly while PTV-Li was also moved posteriorly, showing the same tendency. These observations suggest that the position of St is affected more by the positional change of the mandibular anterior teeth more than that of the maxillary anterior teeth.

In the case of anterior cross bite, the horizontal position of the lower lip is affected by the position of the labial surface of mandibular anterior teeth. This may account for the posterior displacement of the lower lip accompanying posterior displacement of the mandible and mandibular anterior teeth. However, since the maxillary anterior teeth are positioned more anterior to the mandibular anterior teeth after surgery, the horizontal positions of the lower lip and St are affected by the position of the labial surface of maxillary anterior teeth.

PTV-Li and PTV-St were significantly increased, while inferior displacement of St was also observed. The change in St is probably because the upper lip, which was pushed upward by the mandibular anterior teeth before surgery, is displaced inferiorly.

No significant changes in horizontal and vertical positions of the upper lip were observed. Although the upper lip is affected by the positions of the maxilla and maxillary anterior teeth, the amounts of horizontal and vertical displacement of the maxilla and the change in position of maxillary anterior teeth were small in the subjects of this study. Consequently no significant changes were detected.

SPog was displaced posteriorly. The soft tissue chin is most likely affected by the position and morphology of pogonion, which may show changes in the same direction accompanying posterior displacement of the mandible.

There were no significant changes in cheek line between pretreatment and posttreatment. In Le Fort I, cut line runs horizontally from the piriform limb to the maxillary tuberosity, and the horizontally transected maxilla is displaced anteriorly on the superior side of the nasal floor. Therefore, this procedure has just little effect on the morphology of the midfacial

hard tissue (17). This may account for the small changes in the cheek line.

For the horizontal lip and chin position, the multiple correlation coefficients R ranged from 0.89 to 0.95, indicating a high precision of the prediction equations obtained in this study. Among the reports on prediction equations obtained by multiple regression analysis of soft tissue changes following mandibular setback surgery, some showed that the hori-

zontal variables have higher predictive precision than vertical variables (24). For the assessment of these prediction equations, another case of mandibular prognathism accompanying maxillary hypoplasia was prepared. Fig.10 shows the result of simulation using the regression model.

For the horizontal position of the cheek line, the multiple correlation coefficients R ranged from 0.65 to 0.84, showing a moderate precision of the present study. In addition, the results of simulation are shown in Fig. 11. The result of analysis indicates that the prediction equation for lips and chin has a high precision and can be applied to predict soft tissue profile in two-jaw surgery.

In surgical orthodontic treatment by two-jaw surgery, prediction of facial soft tissue changes is important for treatment planing with facial esthetic (25). In the future, soft tissue profile changes in facial asymmetry cases, among various surgical modalities, and for different directions of displacement of maxilla and mandible are topics of further studies.

Fig. 10. The result of simulation using the regression model (profile).

Anterior movement of Maxilla : 2 mm.

Posterior movement of Mandible : 7 mm.

$$PTV-Sn : 0.49(PTV-L1) + 0.58(PTV-Pr) + [-0.50(PTV-ANS)] + 3.52 = 0.25$$

$$PTV-SnLs : 0.45(PTV-U1) + 0.55(PTV-Pr) - 0.32 = 1.68$$

$$PTV-Ls : 0.31(PTV-B) + 0.93(PTV-Pr) + [-0.72(PTV-A)] + 2.37 = 0.62$$

$$PTV-St : 0.72(PTV-L1) + 0.92(PTV-Pr) + [-0.59(PTV-A)] + 0.84 = -3.54$$

$$PTV-Li : 0.69(PTV-Pr) + 0.32(PTV-B) - 3.92 = -4.78$$

$$PTV-SPog : 1.80(PTV-B) + [-2.00(PTV-L1) + 0.58(PTV-Pr) - 5.47 = -2.91$$

Fig. 11. The results of simulation using the regression model (cheek line).

Anterior movement of Maxilla : 2 mm.

Posterior movement of Mandible : 7 mm.

$$PTV-1 : 0.78(PTV-B) + [-0.47(PTV-Pog)] + 2.81 = 0.64$$

$$PTV-2 : 0.58(PTV-Pog) + 5.33 = 1.27$$

$$PTV-3 : 0.50(PTV-L1) + 2.96 = -0.54$$

$$PTV-4 : 0.80(PTV-L1) + [-0.28(PTV-Id)] + 1.18 = -2.46$$

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