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Longitudinal study on skeletal changes during and after bionator therapy using metallic implants

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Abstract

Aim: To demonstrate the magnitude and direction of skeletal changes in the maxilla and mandible during and after the use of bionator, as well as their rotations. **Methods:** Partial superimposition on the maxilla and mandible on the metallic implants and total superimposition on the cranial base were performed at three periods, T1 before bionator therapy, T2 after bionator therapy, and T3 5.68 years after T2. **Results:** There was total clockwise maxillary rotation and counterclockwise mandibular rotation, in the North American technique, throughout the study period, as well as extensive remodeling on the condylar region, especially in vertical direction and on the gonial region in horizontal direction. **Conclusions:** The total maxillary rotation seemed to be significantly affected by therapy than the mandible. There was a clear change in the direction of condylar remodeling compared to the period of bionator therapy and posterior bionator therapy. Considering the entire study period, it was observed that intra-matrix rotation of the maxilla and mandible masked their total rotation, causing minimum changes in the matrix rotation.

Keywords: Angle's class II malocclusion, activator appliances, maxillofacial development.

Introduction

In the Class II malocclusion, mandibular retrusion seems to be a common characteristic and the major factor contributing to the problem[1]. Therefore, the best therapeutic approaches should promote forward mandibular positioning.

Although these appliances are able to redirect the condylar growth, there is no consensus on their capacity to increase the amount of condylar growth[2-7]. In the maxilla, these appliances may promote some restriction of sagittal growth[3,8]. After correction of the distal occlusion, there is a tendency to return to the original condition, both dental and skeletal[5-6].

Cephalometric studies with superimposition on metallic implants were demonstrated to be the most effective method for longitudinal evaluation of craniofacial growth on cephalograms[9-11] and thus are also valid to evaluate the treatment changes. No study has longitudinally analyzed the maxillary and mandibular remodeling in patients submitted to treatment of Class II malocclusion with bionator by partial superimposition on metallic implants. This study evaluated the magnitude and direction of skeletal changes occurring in the maxilla and mandible during and after bionator therapy, as well as their rotations, using lateral cephalograms of patients with metallic implants.

Material and methods

This study was approved by Research Ethic Committee of the FOAr-UNESP

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(no. 0006.0.199.000-07) and informed consent was obtained from the parents of all patients. The treated sample comprised 25 patients who used bionator, who participated in a previous study[2]. The design and treatment approach is described in the previous study[2]. All patients presented clinically observed skeletal Class II malocclusion with mandibular retrusion, erupted or erupting maxillary and mandibular incisors, deep bite, no missing teeth, absence of crowding, and/or posterior crossbite. The patients also presented four metallic implants placed in the maxilla and three in the mandible, as suggested by Björk[12-13]. From the original sample of 25 patients, it was possible to obtain long-term cephalograms of 13 patients (Table 1 and 2), nine males and four females with 9.34 years at T1, 11.21 at T2 and 16.89 at T3. Eleven of these patients (84.6%) received complementary treatment with fixed appliance and class II elastics after the bionator therapy. The other patients could not be contacted.

Lateral cephalograms were obtained at three periods: T1, at the onset of bionator therapy; T2, at the completion of bionator therapy; and T3, 5.68 years after T2 in the average. The cephalograms were manually traced, the cephalometric points were digitized twice on the software SPSS version 10.0 (SPSS Inc., Chicago, IL, USA) by a single examiner, and the mean of digitizations was used for the cephalometric measurements. The cephalometric points analyzed are described in Table 3.

A reference system composed of a horizontal line (HL) and a perpendicular vertical line (PVL) was defined on the cephalogram T1 and transferred to the other cephalograms based on the partial superimposition on maxillary and mandibular metallic implants. Initially, three fiducial points were identified on the tracing T1, the first in front of the maxilla and mandible, the second behind, and the third above this (Figures 1 and 2).

The HL and PVL were defined as follows:

Horizontal line (HL): line contacting the Anterior Fiducial Point and the Posterior Fiducial Point. The line corresponds to the X axis of the reference system.

Perpendicular Vertical Line (PVL): line perpendicular to HL through the Upper Fiducial Point. The line corresponds to the Y axis of the reference system (Figures 1 and 2).

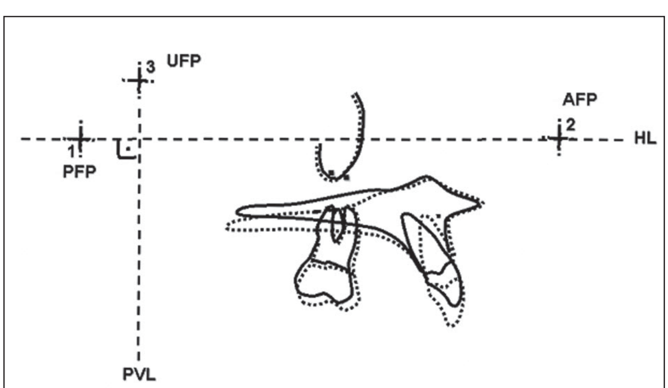

Fig. 1. Partial superimposition on the maxilla, transference of the three fiducial points (1, Posterior Fiducial Point-PFP; 2, Anterior Fiducial Point-AFP; 3- Upper Fiducial Point-UFP), and construction of HL(Horizontal Line) and PVL(Posterior Vertical Line).

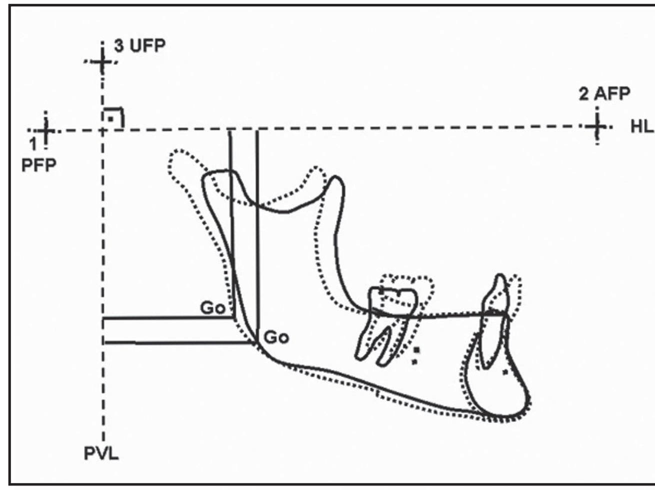

Fig. 2. Partial superimposition on the mandible, transference of the three fiducial points, and construction of HL(Horizontal Line) and PVL(Posterior Vertical Line).

Table 1 - Characteristics of the study sample

Individuals	n	T1 Mean (years)	T1 SD	T2 Mean (years)	T2 SD	T3 Mean (years)	T3 SD
Males	9	9.25	1.39	11.08	1.28	16.99	1.62
Females	4	9.55	1.01	11.52	1.7	16.68	2.9
Total	13	9.34	1.25	11.21	1.36	16.89	1.72

T1 - (treatment onset); T2 - (completion of bionator therapy); T3 - (final evaluation).

Table 2 - Sagittal and vertical angular cephalometric measurements.

Measurements	T1 Mean	T1 SD	T2 Mean	T2 SD	T3 Mean	T3 SD
SNA	82.92º	4.0	81.53º	3.9	81.26º	4.4
SNB	76.75º	3.5	77.56º	3.9	78.20º	4.3
ANB	6.17º	1.9	3.96º	2.3	3.05º	2.6
SN GoMe	32.91º	5.3	33.57º	5.9	31.73º	6.4
FMA	23.49º	3.8	23.86°	4.4	22.33º	5.4
SN-ANS-PNS	5.98º	2.7	6.78º	4.2	6.43º	3.5

The changes occurring in cephalometric points during and after treatment were evaluated in relation to the reference system. For example, the horizontal change in the position of the Gonion (Go) was measured parallel to HL, and the vertical change was measured parallel to PVL (Figure 2). Negative values correspond to backward and/or upward displacement. Positive values were assigned to forward and/or downward displacement. The displacement of all cephalometric points was measured. To enhance the observation of direction of displacement of cephalometric points, each point was followed by a reference. For example, the horizontal displacement of Go is represented by Go H, the vertical displacement of point Go is represented by Go V, and the total displacement of point Go is represented by Go T. The radiographic magnification was corrected using a correction coefficient of 0.91.

The total and matrix rotations of the mandible and maxilla[11] were defined by the angular change of HL transferred from T1 to the others by total superimposition on the cranial base[11] in relation to the implant line (total rotation) and the mandibular and palatal planes (matrix rotation), respectively,

Table 3 - Digitized cephalometric points.

Cephalometric Points	Description
1. **PFP**	Posterior fiducial point
2. **AFP**	Anterior fiducial point
3. **UFP**	Upper fiducial point
4. **PNS** (Posterior nasal spine)	Most posterior point of the posterior nasal spine
5. **ANS** (Anterior nasal spine)	Most anterior point of the anterior nasal spine
6. **A** (Subspinale)	Most posterior point on the maxillary anterior concavity
7. **B** (Supramentale)	Most anterior point on the mandibular anterior concavity
8. **Pg** (Pogonion)	Most anterior point on the anterior symphyseal contour
9. **Gn** (Gnathion)	Most anterior and inferior point on the anterior symphyseal contour
10. **Me** (Menton)	Most inferior point on the symphyseal contour
11. **Ag** (Antegonial)	Most superior point on the antegonial champher
12. **InfGo** (Inferior Gonion)	Most inferior point of the gonial angle
13. **Go** (Gonion)	Most posterior and inferior point of the gonial angle
14. **PostGo** (Posterior Gonion)	Most posterior point of the gonial angle
15. **Ar** (Articulare)	Intersection between the posterior cranial base and the posterior condylar surface
16. **Co** (Condylion)	Most posterior and superior point of the mandibular condyle
17. **CoSup** (Superior Condylion)	Most superior point of the mandibular condyle

in the North American technique. The intra-matrix rotation[11] (remodeling) was determined by the angular change in the implant line in relation to the mandibular and palatal planes, respectively. For the total and matrix rotation, positive values indicated clockwise rotation and negative values represented counterclockwise rotation. Concerning the intra-matrix rotation, positive values indicated that the mandibular or palatal plane exhibited clockwise rotation in relation to the implant line, whereas negative values indicated counterclockwise rotation.

Statistical Analysis

The mean and standard deviation were calculated for each variable. All the variables submitted a normality test (skewness and kurtosis) and showed normal distribution. The differences among the three periods (T2–T1, T3–T2, and T3–T1) were calculated and the one-sample t-test was used to evaluate the significance of changes in those differences. The significance level was set at 5%. All calculations were performed using SPSS for Windows (version 10.0,SPSS Inc., Chicago, IL, USA.).

To evaluate the error in the location of cephalometric points and digitization procedures, all tracings were redigitized after 2 weeks by the same examiner. The casual method error (Dahlberg formula) did not exceed 0.33º or 0.88mm. The paired t-test (systematic errors) revealed statistically significant systematic error for only 5 of the 112 measurements performed (PostGo V at T1 and T2, Me V at T3, InfGo H at T3, and PNS V at T1). The variation of all measurements was between -0.17 and 0.34 mm for linear measurements and -0.13º and 0.03º for angular measurements.

Results

Superimposition on the maxilla

During bionator therapy, only the PNS exhibited significant change in horizontal direction (mean = -1.52 mm; p = 0.006). Evaluation of the total displacement revealed that all points exhibited statistically significant change. After bionator therapy, point A presented significant vertical change (mean 1.78 mm; p=0.007) and the PNS in the horizontal direction (mean -2.65 mm; p=0.000). Observation of the entire study period revealed significant horizontal change in ANS and PNS and significant vertical change in point A (Figure 3 and Table 4).

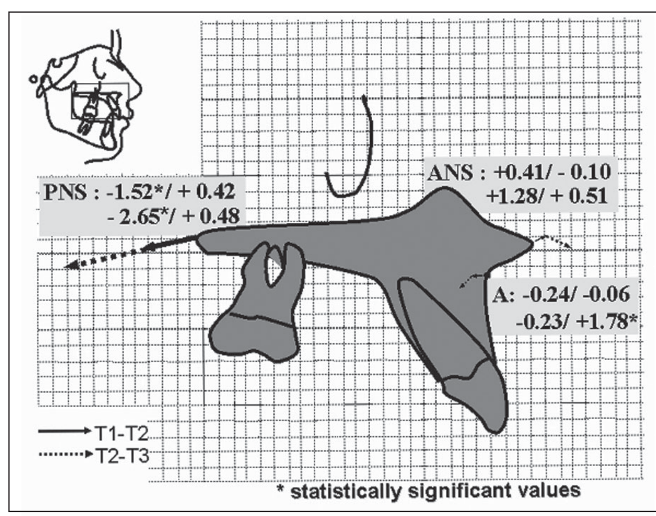

Fig. 3. Maxillary remodeling between T1 and T2 (upper data) and between T2 and T3 (lower data). The horizontal/vertical components are proportional in scale. Each square represents 0.5 mm.

Table 4 - Maxillary growth (vertical, horizontal and total) and remodeling (in mm).

Variable	T2 - T1		T3-T2		T3-T1	
	Mean (SD)	"p"	Mean (SD)	"p"	Mean (SD)	"p"
PNS V	0.42 (0.9)	0.142^{n}	0.48 (1.8)	0.354^{n}	0.91 (1.8)	0.097^{n}
ANS V	-0.10 (1.4)	0.806^{n}	0.51 (1.4)	0.233^{n}	0.41 (1.4)	0.320^{n}
A V	-0.06 (1.2)	0.863^{n}	1.78 (1.9)	0.007*	1.72 (2.0)	0.011*
PNS H	-1.52 (1.6)	0.006*	-2.65 (1.3)	0.000*	-4.18 (2.0)	0.000*
ANS H	0.41 (1.8)	0.435^{n}	1.28 (2.9)	0.136^{n}	1.70 (2.5)	0.035*
A H	-0.24 (0.7)	0.292^{n}	-0.23 (1.1)	0.493^{n}	-0.47 (1.4)	0.249^{n}
PNS T	2.10 (1.2)	0.000*	3.20 (1.3)	0.000*	4.77 (1.6)	0.000*
ANS T	1.82 (1.4)	0.001*	2.88 (1.9)	0.000*	2.95 (1.5)	0.000*
A T	1.33 (0.6)	0.000*	2.23 (1.8)	0.001*	2.70 (1.3)	0.000*

* = statistically significant values ($p \leq 0.05$); ^{n} = non statistically significant values.

Superimposition on the mandible

During the bionator treatment period, there was statistically significant vertical change in the following cephalometric points: Pg, Ag, InfGo, Go, PostGo, Ar, Co, and CoSup. In the horizontal direction, the following cephalometric points presented a statistically significant change: Ag, InfGo, Go, PostGo, and Ar. After bionator therapy, statistically significant vertical change was observed for the cephalometric points Ag, InfGo, Go, PostGo, Ar, Co, CoSup, Me, Gn, and **point** B. In the horizontal direction, only the points related to the gonial angle exhibited significant change. No significant change was revealed in a horizontal direction only for the points B, Gn, Me, Ar, Co, and CoSup during observation of the entire study period (Figures 4 and 5 and Table 5).

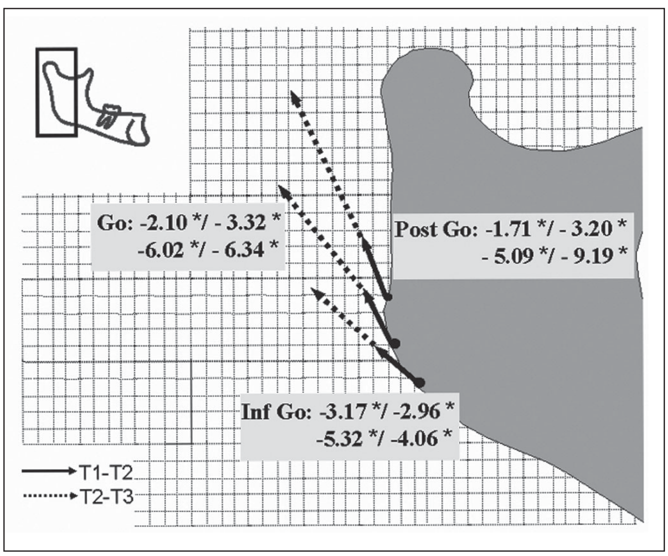

Fig. 5. Remodeling of the gonial angle between T1 and T2 (upper data) and between T2 and T3 (lower data). Horizontal/vertical components are proportional in scale. Each square represents 1 mm.

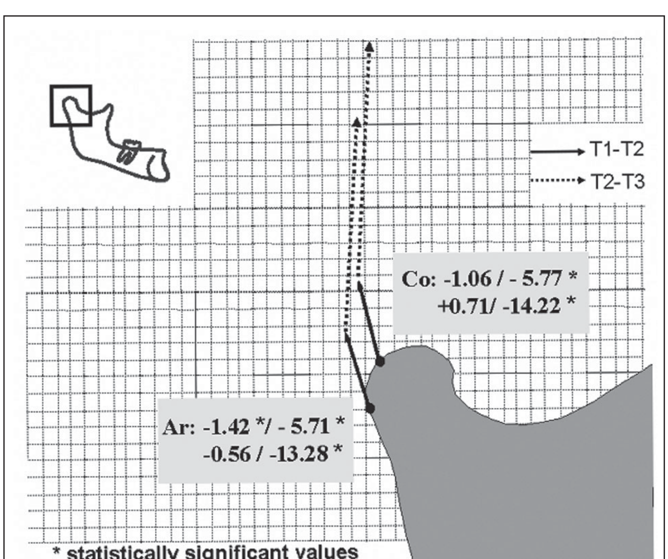

Fig. 4. Condylar remodeling between T1 and T2 (upper data) and between T2 and T3 (lower data). The horizontal/vertical components are proportional in scale. Each square represents 1 mm.

Table 5 - Mandibular growth (vertical, horizontal and total) and remodeling (in mm).

Variable	T2 - T1		T3-T2		T3-T1	
	Mean (SD)	"p"	Mean (SD)	"p"	Mean (SD)	"p"
B V	0.09 (1.3)	0.807^{n}	-1.40 (2.1)	**0.038***	-1.30 (2.0)	**0.045***
Pg V	0.85 (1.3)	**0.038***	0.45 (1.7)	0.376^{n}	1.31 (2.0)	**0.043***
Gn V	0.47 (1.1)	0.169^{n}	0.97 (1.3)	**0.019***	1.45 (1.6)	**0.008***
Me V	0.23 (0.8)	0.329^{n}	1.36 (0.8)	**0.000***	1.60 (1.1)	**0.000***
A Go V	-2.68 (2.5)	**0.003***	-2.68 (1.8)	**0.000***	-5.37 (2.1)	**0.000***
Inf Go V	-2.96 (3.0)	**0.004***	-4.06 (1.9)	**0.000***	-7.03 (3.4)	**0.000***
Go V	-3.32 (4.5)	**0.022***	-6.34 (2.5)	**0.000***	-9.67 (5.7)	**0.000***
Post Go V	-3.20 (5.1)	**0.044***	-9.19 (3.7)	**0.000***	-12.39 (6.4)	**0.000***
Ar V	-5.71 (2.4)	**0.000***	-13.28 (3.1)	**0.000***	-18.99 (3.6)	**0.000***
Co V	-5.77 (3.4)	**0.000***	-14.22 (4.5)	**0.000***	-20.00 (4.0)	**0.000***
Co Sup V	-5.48 (3.1)	**0.000***	-14.13 (4.0)	**0.000***	-19.62 (3.6)	**0.000***
B H	0.12 (0.4)	0.329^{n}	0.06 (0.6)	0.705^{n}	0.19 (0.6)	0.279^{n}
Pg H	-0.46 (0.9)	0.096^{n}	-0.29 (0.6)	0.145^{n}	-0.76 (1.2)	**0.046***
Gn H	-0.49 (1.2)	0.169^{n}	-0.39(0.8)	0.112^{n}	-0.89 (1.6)	0.083^{n}
Me H	-0.26 (1.2)	0.468^{n}	-0.69 (1.0)	0.031^{n}	-0.96 (1.8)	0.089^{n}
A Go H	-3.57 (2.6)	**0.000***	-3.96 (2.7)	**0.000***	-7.55 (1.8)	**0.000***
Inf Go H	-3.17 (3.0)	**0.002***	-5.32 (1.7)	**0.000***	-8.50 (2.3)	**0.000***
Go H	-2.10 (2.1)	**0.005***	-6.02 (1.6)	**0.000***	-8.12 (1.7)	**0.000***
Post Go H	-1.71 (1.6)	**0.003***	-5.09 (1.6)	**0.000***	-6.81 (1.5)	**0.000***
Ar H	-1.42 (2.2)	**0.039***	-0.56 (2.2)	0.386^{n}	-1.99 (3.7)	0.080^{n}
Co H	-1.06 (2.8)	0.201^{n}	0.71 (2.9)	0.405^{n}	-0.35 (4.9)	0.802^{n}
Co Sup H	-1.23 (2.9)	0.160^{n}	1.24 (2.9)	0.150^{n}	0.01 (4.7)	0.993^{n}
B T	1.19 (0.7)	**0.000***	1.92 (1.7)	**0.002***	1.84 (1.7)	**0.002***
Pg T	1.40 (1.2)	**0.001***	1.57 (1.1)	**0.000***	2.08 (1.9)	**0.002***
Gn T	1.50 (0.9)	**0.000***	1.52 (1.0)	**0.000***	2.32 (1.7)	**0.000***
Me T	1.19 (0.9)	**0.001***	1.81 (0.9)	**0.000***	2.44 (1.4)	**0.000***
A Go T	4.81 (3.2)	**0.000***	4.91 (3.1)	**0.000***	9.37 (2.4)	**0.000***
Inf Go T	4.87 (3.5)	**0.000***	6.85 (2.0)	**0.000***	11.21 (3.6)	**0.000***
Go T	4.94 (3.9)	**0.001***	8.93 (2.3)	**0.000***	12.97 (5.1)	**0.000***
Post Go T	5.26 (3.6)	**0.000***	10.69 (3.4)	**0.000***	14.63 (5.3)	**0.000***
Ar T	6.31 (2.3)	**0.000***	13.44 (3.2)	**0.000***	19.41 (3.7)	**0.000***
Co T	6.56 (3.2)	**0.000***	14.54 (4.4)	**0.000***	20.52 (4.3)	**0.000***
Co Sup T	6.37 (2.9)	**0.000***	14.52 (3.8)	**0.000***	20.11 (3.8)	**0.000***

* = statistically significant values ($p < 0.05$); ^{n} = non statistically significant values.

Maxillary and mandibular rotation:

Table 6 shows that during the period of bionator therapy, only the total mandibular rotation presented significant change (mean = -1.74º; p = 0.047). After bionator therapy, the total mandibular rotation (mean= -3.96º; p= 0.004) and mandibular intra-matrix rotation (mean= 2.78º; p=0.004) exhibited significant change. During the study period, no significant change was observed in matrix rotations for both the maxilla and the mandible.

Discussion

Despite the small sample size and lack of control group, this study may be considered of interest to the scientific community because of the presence of metallic implants and longitudinal follow-up of the same patients. This allowed a detailed analysis of maxillary and mandibular growth in patients with Class II malocclusion submitted to orthopedic treatment using the Balters functional appliance.

There was progressive closure of the angle of the mandibular implant line (counterclockwise rotation), that is, the total mandibular rotation[9,11,14-15]. In addition to the treatment period, there was counterclockwise rotation throughout the study period. Araújo et al.[2] demonstrated that the bionator was able to inhibit the total counterclockwise mandibular rotation. The rotation observed in the present study (1.74º) was smaller than that observed by Araújo et al.[2] (2.53º) in the control group and higher than the counterclockwise rotation of only 0.17º of the treated group. This confirmed that the appliance has the same influence, that is, inhibiting the total counterclockwise mandibular rotation[6,16]. Björk and Skieller[11] published a case treated with headgear and observed inhibition of counterclockwise mandibular rotation during treatment, which returned after treatment. This is in agreement with the results of Melsen[17] using the same appliance, and Pancherz et al.[6] using the Herbst appliance. The difference in the quantity of rotation between this study and the findings of Araújo et al.[2] may be explained by the longer treatment period of this study, that is, 2 years compared to 1 year. Moreover, as the need of utilization of the appliance is reduced, its influence is also reduced, allowing the natural rotation expected by growth to occur.

The 5.7º mandibular rotation evaluated from T1-T3 was greater than that reported by Buschang and Gandini Jr[14], and Kim and Nielsen[18], 2º to 3.3º and 3.5º, respectively. This is smaller than the values observed by Lavergne and Gasson[19], 12.8º, Björk and Skieller[11], 8.6º, and very close to the value observed by Lee et al. [20], 5.8º. This could probably be because of the longer follow-up period of this study when compared to other studies that had follow-up periods of 7 years[14] and 5 years[18]. However, it is shorter than the 12-year follow-up by Lavergne and Gasson[19] and 15-year follow-up by Björk and Skieller[11], and similar to that of Lee et al.[20] Several studies[9,14,16,19,21] have revealed that patients with greater counterclockwise rotation exhibit more vertical condylar growth. Analysis of the rotation occurring per year reveals a mean of 0.77º/year, close to the values observed by other authors[11,16,20-22] (Table 7), demonstrating that the influence of bionator is reduced with time.

In the maxilla, the total rotation occurred in clockwise direction and in lower intensity. The most variable behavior of maxillary rotation, which may occur in two directions and in lower intensity compared to the mandibular rotation, is reported in the literature[10,15,23] and agrees with the present findings, revealing a variation of -4.6º to 10.8º. The results of this study also revealed clockwise maxillary rotation during and after bionator therapy, which was greater during treatment, 0.8º/year, than after treatment, 0.23º/year. The total counterclockwise maxillary rotation is the most common[9-10,15,24] and the clockwise rotation might be an outcome of treatment using headgear[17] and the activator[7]. Clockwise maxillary rotation was also observed after bionator therapy, considering that these patients received fixed appliances and used Class II elastics at some period, the influence of the entire Class II mechanics on the total clockwise maxillary rotation may be inferred as Melsen[17] observed inversion in the direction of total maxillary rotation after treatment of the Class II malocclusion. Table 8 demonstrates that the smaller total maxillary rotations are related to studies whose samples also included treated patients, highlighting the influence of the mechanotherapy for Class II malocclusion in most cases, thus promoting clockwise maxillary rotation.

Table 6. Maxillary and mandibular rotation.

Variable	T2 - T1		T3-T2		T3-T1	
	Mean (SD)	"p"	Mean (SD)	"p"	Mean (SD)	"p"
Matrix Maxilla	0.29 (1.8)	0.583^{n}	0.20 (2.2)	0.753^{n}	0.49 (2.7)	0.524^{n}
Matrix Mandible	0.04 (2.3)	0.950^{n}	-1.21 (3.3)	0.213^{n}	-1.17 (3.2)	0.214^{n}
Total Maxilla	1.36 (2.5)	0.075^{n}	1.49 (4.2)	0.225^{n}	2.85 (4.6)	**0.045***
Total Mandible	-1.74 (2.8)	**0.047***	-3.96 (3.9)	**0.004***	-5.7 (4.9)	**0.001***
Intra-matrix Maxilla	-1.30 (3.5)	0.208^{n}	-1.17 (3.9)	0.307^{n}	-2.47 (3.8)	**0.038***
Intra-matrix Mandible	1.79 (4.6)	0.189^{n}	2.78 (2.8)	**0.004***	4.57 (5.2)	**0.008***

* = statistically significant values ($p \leq 0.05$); ^{n} = non statistically significant values.

Table 7. Yearly changes in the mandibular total rotation in studies on metallic implants – available data.

Authors^reference	Type of malocclusion	Patients*	n	Degrees/ year	Interval in years
Gu, McNamara[21]	I and II	A	20	-0.78º	9 -15.6
Lavergne, Gasson[19]	several	A	26	-1.07º	7-19
Araújo et al.[2]	II	T	14	-0.17º	9.5-10.5
Araújo et al.[2]	II	UT	11	-2.53º	9-10
Gasson, Lavergne[15,22]	several	A	22	-0.81º	7-16
Björk, Skieller[9]	I, II and III	UT	21	-1º	6-year follow up
Björk, Skieller[11]	I	UT	9	-0.78º	4 -19.7
Lee et al.[20]	several	A	28	-0.74º	8.5-16.2
Odegaard [16]	several	A	25	-0.78º	2.5-year follow up
Present study	II	T	13	-0.77º	9.34-16.89

*T= treated patients; UT= untreated patients; A=both; + indicates clockwise rotation / - indicates counterclockwise rotation.

Table 8. Yearly changes in the maxillary total rotation in studies on metallic implants – available data.

Authors^reference	Type of malocclusion	Patients*	n	Degrees/ year	Interval in years
Gasson, Lavergne[15,22]	several	A	22	-0.21º	7-16
Solow, Iseri[24]	several	UT	14	-0.38º	8.5-12.5
Björk, Skieller[9]	I, II and III	UT	19	-0.42º	6-year follow up
Björk, Skieller[11]	I	UT	9	-0.41º	10 -19.7
Doppel et al.[23]	I, II and III	A	50	-0.13º	12-16
Present study	II	T	13	+0.36º	9.34-16.89

* T = treated patients; UT = untreated patients; A = both;
\+ indicates clockwise rotation / - indicates counterclockwise rotation.

Solow and Iseri[24] observed 2.5º of posterior maxillary intra-matrix rotation from 8 to 15 years. This study also observed nearly 2.5º rotation in the anterior direction, probably as a remodeling to compensate for the total clockwise rotation occurring as a result of treatment[10,12,23]. As previously mentioned in the literature[9-12,16], because there is total counterclockwise rotation and the matrix rotation is very subtle, there is remodeling of the mandibular base and palatal plane to compensate for the rotation. The maxilla exhibited clockwise total and matrix rotation, and remodeling occurred more by vertical displacement of the PNS, compared with the ANS. This is in agreement with the treated group of Baumrind et al.[25], suggesting that the orthodontic treatment may interfere with the maxillary remodeling, as untreated groups[24-25] present greater vertical displacement of the ANS than of the PNS. The final outcome was an increase in the maxillary matrix rotation of only 0.5º in the present study and 1º in the study of Solow and Iseri[24], revealing minimum change in the palatal plane angle, in agreement with other authors[12,15,23], as also observed in Table 2.

The results demonstrate nearly 4.6º of opening of the angle between the implant line and the mandibular base. This intra-matrix rotation occurred because of upward remodeling of the gonial angle and downward displacement of the Me, as presented in Table 5. During the treatment period, the mandibular matrix rotation remained unchanged (0.04º) and during the second period there was a slight closure (-1.21º), also identified by reduction in the angles SNGoMe and FMA (Table 2).

Throughout the study period and also during the treatment, there was extensive backward and upward remodeling of the gonial region, especially of the Go and PostGo points, agreeing with previous reports.[11-14,21,26] Figure 5 reveals that this region did not exhibit changes in the direction of growth between the study periods, maybe because it is less susceptible to the environment[14].

At the symphyseal region, there was apposition on the lower part and upward repositioning of point B and downward repositioning of points Pg, Gn, and Me, in agreement with other studies[14,26]. In the horizontal direction, there was stability of cephalometric points at the Me region, agreeing with the studies of Björk[11,13].

The condylar region exhibited the greatest vertical changes in the mandible[14,26]. During the treatment period, there was backward condylar growth[2-6,8]. After bionator therapy, the condylar growth was redirected in anterior direction, returning almost totally to the initial anteroposterior condylar positioning. Studies[11-13,26] revealed that the condyle presents upward and forward growth of nearly 6º in relation to the mandibular posterior border in untreated patients and forward growth of 10º in patients with total counterclockwise mandibular rotation. This information suggests that the backward growth obtained by treatment might be statistically significant when compared with a control group. Some of the patients in the present sample were followed for 1 year without treatment in a previous study[2] and presented anterior condylar growth during this period. After use of the bionator, Faltin et al.[4] demonstrated stability of condylar redirectioning in patients treated during the peak growth spurt. The results of this study do not support these findings[3-4], probably because they were treated before the peak growth. However, the results agree with other studies[5-6].

The posterior displacement of point A observed in this study was nearly 0.5mm, probably because of the natural resorption occurring on the maxillary anterior region[24-25] combined with the Class II mechanics employed[25]. In the vertical direction, the differences occurred because of the intra-matrix rotation, which presented a different direction in this study compared to earlier reports. Concerning the PNS point, the authors observed downward and backward displacement[24]. The PNS always presents backward growth, both in the treated and untreated groups, and also exhibits greater displacement of the ANS, which is the primary mechanism of maxillary growth[25].

In conclusion, the total maxillary rotation seemed to be significantly affected by therapy than the mandible. There was a clear change in the direction of condylar remodeling compared to the period of bionator therapy and posterior bionator therapy. Considering the entire study period, it was observed that intra-matrix rotation of the maxilla and mandible masked their total rotation, causing minimum changes in the matrix rotation.

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