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Original Article

Condylar positioning in orthognathic surgery: a cone beam computed tomography-based in vitro analysis of a positioning method

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Aim: Orthognathic surgery aims to correct facial skeletal deformities and the correct condylar positioning is very important for stable results. The aim of the present study was to verify the occurrence of changes in the postoperative condylar positioning in artificial skulls with a skeletal Class II maxillomandibular relationship submitted to bilateral sagittal split osteotomy when the method of cephalometric data transfer was used. **Methods:** Ten skeletal Angle class II polyurethane skulls were used with metallic markers in the articular surfaces of the temporomandibular joint and mandibular condyles. The skulls were submitted to preoperative and postoperative cone beam computed tomography before and after the bilateral sagittal split osteotomy. To verify the condylar positioning, measurements between the distances of the markers at the temporal bones and mandibular condyles were taken in the coronal and sagittal views by the *DISTANCE* tool of the iCat Vision software. All measurements were obtained by one examiner in the preoperative and postoperative CBCTs, tabulated and submitted to statistical analysis by the Wilcoxon test with a level of significance of 5% (p<0,05). After 15 days of the completion of the first data collection, all measurements were redone to determine the random and systematic error by the Intraclass Correlation Coefficient. **Results:** With the exception of the average of the lateral-medial distance (from the measurements between the medium left markers only), the averages of the anterior-posterior distances (only in the left posterior and lateral right markers) and the vertical

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average (only in the central markers) showed no statistically significant differences between the preoperative and postoperative distances of the metallic markers. **Conclusion:** Even when using the method of cephalometric data transfer, variation of the condylar positioning occurred between the preoperative and postoperative periods. This variation occurred only in a few points of the mandibular condyles.

Keywords: Orthognathic surgery. Mandibular condyle. Computed tomography.

Introduction

Facial skeletal deformities can be characterized by the underdevelopment or hyper-development of the facial bones, especially in the maxilla and mandible; such changes might occur in the transverse, anterior-posterior and vertical directions[1]. The aim of orthognathic surgery is the correction of these deformities[2,3] and it is performed with the use of Le Fort I osteotomy (in cases where the maxilla is involved), bilateral sagittal split osteotomy of the mandible (in cases involving the mandible) or the association of both osteotomies (in cases where the maxilla and the mandible are involved)[4].

There are effects on the condyles following the correction of facial skeletal deformities even in isolated maxillary deformities[5] and during the execution of mandibular orthognathic surgery, the correct positioning of the condyle, and consequently the mandibular proximal segment, is essential for better and stable results. The inappropriate positioning of this segment is undesired[6] and may result in recurrence, loss of mandibular angle, condylar displacement, pain, temporomandibular joint (TMJ) dysfunction and disability[7].

Several methods and devices to control the positioning of the proximal segment have been suggested over the years[8] with good results[9-18] or not[19,20], maintaining unanswered questions on this topic[21]. There is no scientific evidence supporting the routine use of condylar positioning devices (CPD) in orthognathic surgery[19,22].

In this context, there is no scientific evidence that desired postoperative condilar position is the same pre-operative condylar position, and there are many reasons for this[17]. However, it seems to be acceptable that if there aren't pre-operative signs and symptoms of TMJ problems, the pre-operative condyle position is good and it is desired in the postoperative moment.

According to Perez and Liddell[23], there are few reliable data regarding the possibility of the CPD maintaining the condyle in the desired position during orthognathic surgery or if this is relevant for success. More important than which CPD is the best, is to be certain with respect to the passive position of the proximal segment[23].

The aim of the present study was to verify the occurrence of changes in postoperative condylar positioning in artificial skulls with a skeletal Class II maxillomandibular relation submitted to bilateral sagittal split osteotomy when the method of cephalometric data and surgical plan transfer were used[13,14].

Materials and Methods

Ten artificial skulls developed in hard polyurethane with barium (Nacional Ossos, Jau - SP) were used. They consisted of skeletal class II types and had the muscles of mastication and presented metallic markers (titanium screw with 5mm diameter and 5mm length) at the medial, anterior, posterior and lateral ends of the joint cavity and in the center of the joint cavity. There were also markers at the lateral, medial, anterior and posterior poles of the condyle joint surface and in the center of the mandibular condyle joint surface. Such markers were installed bilaterally by the team of researchers, seeking to install them in a coincidental manner between the glenoid fossa and the condyle (Figure 1).

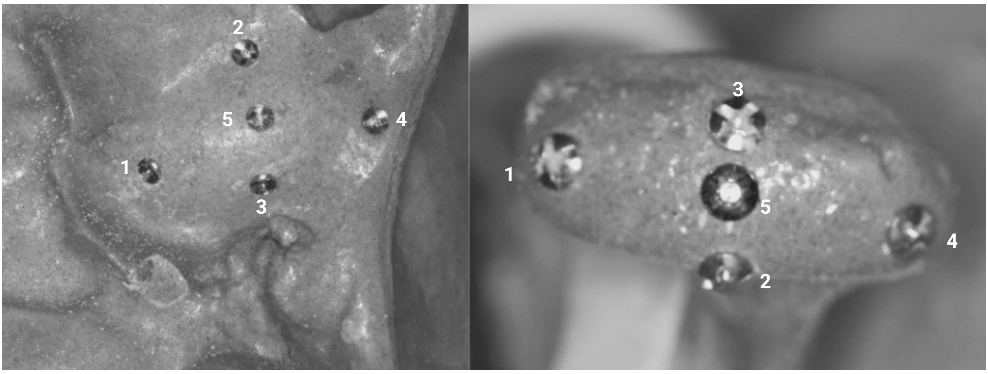

Figure 1. Metallic markers at the medial (1), anterior (2), posterior (3) lateral (4) and central (5) positions of the glenoid glenoid fossa and condyle.

All screws were inserted with the use of a cylindrical drill 1.1mm in diameter and a manual screw driver. After the installation of the markers, the skulls were submitted to preoperative CBCT (Group 1: control). The scans were performed on an i-CAT Classic (Imaging Science International, Hatfield, Pennsylvania, USA) using the following protocol: 0.3mm voxel and Extended Height 20/20sec.

Next, they were submitted to the mandibular advancement procedure, which was performed by means of bilateral sagittal split osteotomy of the mandible with advancement of 10mm using the cephalometric data and surgical plan transfer method[13,14], which can be summarized as follows: sagittal osteotomy was performed on the mandible on one side without the split. The 2.0 system four role plate was positioned in the oblique line, parallel to the mandible occlusal plane and screwed with 2 screws only in the proximal fragment. With a 1/2 size spherical bur, the insertion points of the screws on the plate in the distal fragment were drilled and the plate was removed. New holes were done with a surgical ruler 10mm distal from the holes done with the 1/2 size spherical bur. Next, new holes were drilled again with the 1.5 drill to the 2.0 plate system. We proceeded with the sagittal split osteotomy of the mandible, put the plate again in the proximal segment with screws in the same holes that were first screwed in the distal fragment of the mandible in the holes that were screwed with the 1.5 drill. This automatically advanced the mandible 10mm (Figure 2 and 3). This sequence was done bilaterally.

After completion of the mandibular advancement (Figure 3), the same 10 skulls were again submitted to postoperative CBCTs (Group 2: Experimental) to verify the condylar positioning of both groups (Control and Experimental) via the measurement of the lateral-medial distances (in coronal reformatting), anterior-posterior and vertical distances (both in the sagittal reformatting) that were measured between the long axis of the metallic markers installed in the glenoid fossa and in the mandibular condyle,

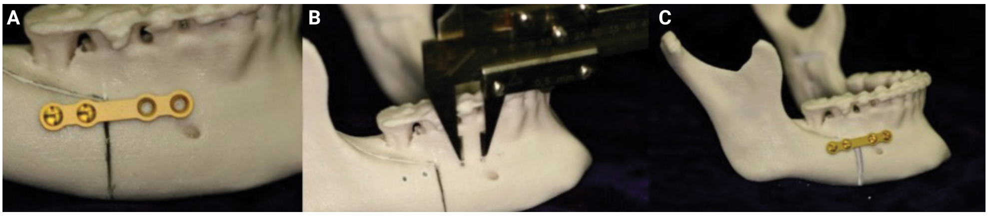

Figure 2. View of the sagittal split osteotomy (without the split at this moment) in a mandible prototype with a plate and 02 screws in the proximal fragment and the holes done with a number 1/2 spherical bur inside the plate holes at the distal fragment (A). After removal of the plate, the digital caliper measured 5mm to the posterior position from the two holes done with the 1/2 spherical bur. These two news holes will be the screw holes for the plate in the distal fragment (B). Then the split is done and the distal fragment moves forward and the plate and the four screws return to their original position (two in the holes of the proximal fragment and two in the new holes 5mm back in the distal fragment). In this example, the mandible will automatically be advanced 5mm (C)

Figure 3. Lateral view of artificial skull after 10mm mandibular advancement.

always at the level of the head of the screw located in the condyle and perpendicular to the long axis of the same.

All scans were performed on an i-CAT Classic (Imaging Science International, Hatfield, Pennsylvania, USA) using the following protocol: 0.3mm voxel and Extended Height 20/20sec. The Cone Beam Computed Tomography (CBCT) was filed on a portable hard drive and the linear measurement tool (DISTANCE) of the i-Cat Vision program was used for obtaining the measurements as described below;

The measurement of the changes between the distances of the metallic markers (screws) on the coronal reformatting were done via the demarcation of the lines that matches the long axis of the screws with the use of the *DISTANCE* tool of the software at the level of the screw head, perpendicular to the lines previously marked and then the distance between the lines were measured (Figure 4). The measurement of the changes between the anterior-posterior distances of the metallic markers (screws) on the sagittal reformatting began with the demarcation of the lines in blue and red, which represented the long axis of the screws and were done using the *DISTANCE* tool of the software. At the top of the screw head in the condyle, the distance between the lines were measured perpendicularly (Figure 5). The measurement of the changes between the vertical distances of the metallic markers (screws) on the sagittal reformatting were done via the demarcation of perpendicular lines from the top of the head of the screws using the *DISTANCE* tool of the software and then the distance between them were measured (Figure 6).

All measurements were obtained by one examiner in the preoperative and postoperative CBCTs, tabulated and submitted to statistical analysis by the Wilcoxon test with

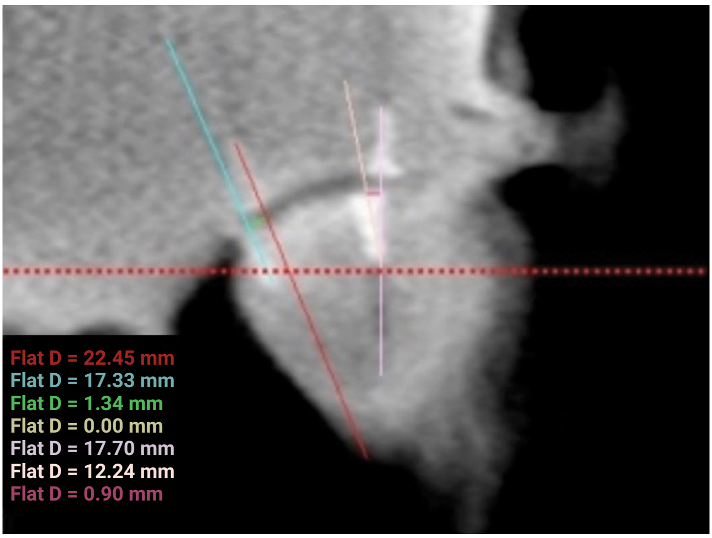

Figure 4. Measuring the changes between the distances of the metallic markers (screws) on the coronal reformatting. Lines (blue, red, pink and light pink) representing the long axis of the screws were done using the *DISTANCE* tool of the software at the level of the screw head of the condyle, perpendicular to the lines previously marked, representing the long axes of the screws, and the distance between the lines were measured. In this picture, the distances between the lines of the long axes of the screws of the glenoid fossa and condyle were 1.34 mm and 0.90 mm (green and purple lines).

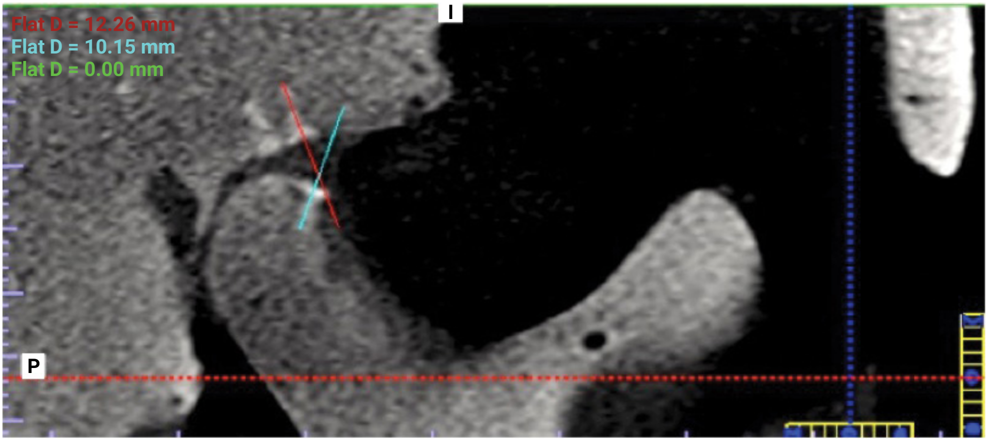

Figure 5. Measuring changes between the anterior-posterior distances of the metallic markers (screws) on the sagittal reformatting. Lines (blue and red) representing the long axis of the screws and were done using the *DISTANCE* tool of the software. At the top of the screw head of the condyle, the distance between the lines (blue and red) were measured perpendicularly (green result that is showed at the picture upper left corner = 0.0mm).

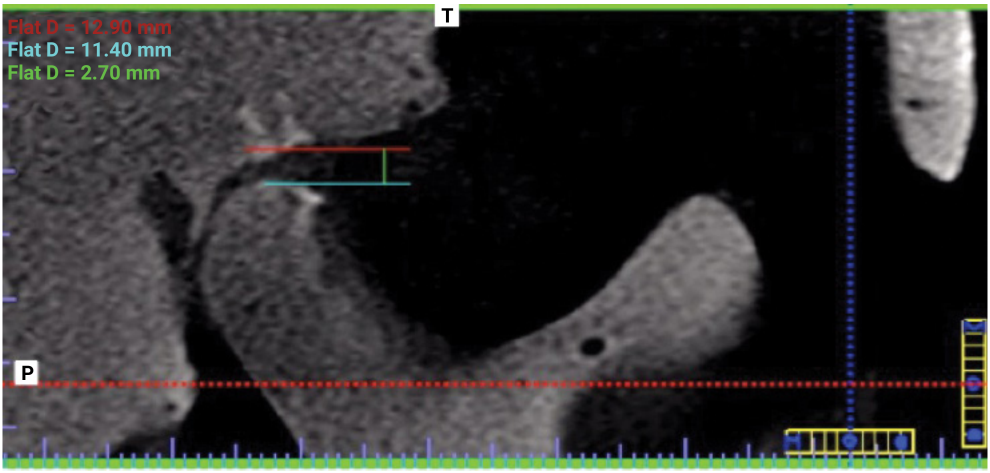

Figure 6. Measuring changes between the vertical distances of the metallic markers (screws) on the sagittal reformatting. Perpendicular lines (blue and red) from the top of the head of the screws were done using the *DISTANCE* tool of the software and the distance between them were measured (green vertical line). In this picture, the green line represents the vertical distance between the upper and lower lines and it was 2.70 mm

a level of significance of 5% (p<0,05). After 15 days of the completion of the first data collection[24], all measurements were redone to determine the random and systematic error by the Intraclass Correlation Coefficient (ICC)[25].

Results

The results showed that, with the exception of the average of the medial-lateral and medial distances (only between the metallic markers on the left side), and the anteri-or-posterior middle distances (only in the positions of the left posterior and lateral right side markers) and the vertical average (only in the positions of the central markers), there were no statistically significant differences between the pre and post distances of the screws (metallic markers). Tables 1 to 3 show the averages, standard deviation (SD) and the result of the statistical test of the distances between the screws at the glenoid fossa and mandibular condyle in the preoperative and postoperative periods of both sides in the coronal reformatting (medial-lateral measures) and sagittal reformatting (anterior-posterior and vertical measures).

For error analysis, the ICC was used; all measures were carried out by the same examiner, respecting the time of no less than 15 days. The ICC was excellent since all their values were greater than 0.75.

Table 1. Averages, standard deviation (SD) and statistical test result of the distances between the screws at the glenoid fossa and mandibular condyle in the preoperative and postoperative periods of both sides. *Significant (p <0.05).

Side	Screw	Pre	Post
	Lateral	1.47 (1.18)	1.5 (0.75)
	Central	1.39 (0.52)	1.5 (0.97)
Right	Medial	2.52 (1.09)	2.58 (0.79)
	Anterior	1.41 (0.93)	1.32 (1.23)
	Posterior	1.26 (0.78)	1.86 (0.93)
	Lateral	1.74 (0.83)	2.28 (1.13)
	Central	0.63 (0.63)	0.84 (0.85)
Left	Medial *	0.87 (0.81)	1.83 (0.98)
	Anterior	0.72 (0.8)	1.08 (0.79)
	Posterior	0.69 (0.74)	0.69 (0.8)

Table 2. Averages, standard deviation (SD) and statistical test result of the anterio-posterior distance (sagittal reformatting) between the screws of the glenoid fossa and mandibular condyle in the preoperative and postoperative periods of both sides. *Significant (p<0.05).

Side	Screw	Pre	Post
	Lateral*	1.11(0.69)	1.98(0.91)
	Posterior	1.98(1.04)	2.25(1.07)
Right	Central	0.9(0.69)	1.17(0.57)
	Anterior	0.48(0.47)	0.57(0.6)
	Medial	1.08(1.19)	1.02(1.02)
	Lateral	0.96(1.39)	1.83(1.42)
	Posterior*	2.19(1.44)	2.85(1.9)
Left	Central	1.32(0.95)	1.65(1.16)
	Anterior	0.9(1.24)	1.38(1.19)
	Medial	1.95(0.82)	2(0.83)

Table 3. Averages, standard deviation (SD) and statistical test result of the vertical distances (sagittal reformatting) between the screws of the glenoid fossa and mandibular condyle in the preoperative and postoperative periods of both sides. *Significant ($p<0.05$).

Side	Screw	Pre	Post
	Lateral	1.6(0.9)	1.17(0.69)
	Posterior	0.81(1)	0.42(0.42)
Right	Central	0.24(0.30)	0.48(0.45)
	Anterior	1.2(0.95)	1.14(0.54)
	Medial	0.6(0.58)	0.6(0.5)
	Lateral	2.52(0.82)	2.58(1.6)
	Posterior	0.39(0.56)	0.93(1.1)
Left	Central*	0.3(0.4)	0.93(0.76)
	Anterior	1.5(0.76)	1.71(0.77)
	Medial	0.54(0.41)	1.26(1.20)

Discussion

According to Ueki et al.[26], mandibular bilateral sagittal split osteotomy is a procedure indicated for the correction of dentofacial deformities, however, changes in the mandibular condylar position arising from surgery may lead to malocclusion, higher risk of relapse and the development of temporomandibular joint disorders. Epker and Wylie[27], believed that the maintenance of the preoperative anatomical position of the condyle after surgery was important and Luhr[28], defended the use of CPD for maintaining the centric relation and the preoperative condylar position in the postoperative period. Therefore, the use of CPD in some studies was[9-19] considered beneficia[9-18] while in others it wasn`t[19,20] ,allowing Ellis[21] to emphasize that questions related to the use of CPDs remain unanswered. The review conducted by Costa et al.[22] found that there was no scientific evidence to support the routine use of CPDs in orthognathic surgery.

In 1997 and 2007, Puricelli[13,14] published a method based on the use of the fixation plate to transfer the cephalometric data and surgical plan during orthognathic surgery that might keep the original position (preoperative) of the mandibular condyle. The method in that *in vitro* study seems to be effective in maintaining the preoperative position of the mandibular condyle, because, even with few exceptions, no other portion (either left or right condyle) showed statistically significant variations between the preoperative and postoperative periods in a 10mm mandibular advancement.

However, standing out in this context, the methodology employed in that study may have interfered in the results because it was an "*in vitro*" study done on an artificial skull without the muscles that obviously reproduce the characteristics of living human tissue. The TMJ employed, for example, did not have a capsule and articular disk. In addition, the artificial muscle texture differed from the natural musculature. In this context, Puricelli et al.[29] analyses by Finite Element Analysis (FEM), the same osteotomy used in that study, stated that their results suggest, *in vivo*, larger and more adjusted bone contact among bone fragments and decreased displacement due to muscle activity. Nevertheless, the method employed in that study proved to be simple and applicable and may give us important information regarding the positioning of the mandibular condyle in orthognathic surgery, with the use or not of CPD. It should be noted that the experimental model used has limitations as exposed above, and it becomes a necessary caution to extrapolate these findings to real-life situations, and that further studies with experimental models closer to living humans appear to be necessary.

A good question would be: why did only 4 points measured showed statistically significant changes between the preoperative and postoperative periods? It is believed that this occurred because of the rotational asymmetric condylar movements that interfered solely with the positioning of the markers in specific positions (medial markers on the left side in the coronal reformatting, lateral-medial measures, lateral right and posterior left markers in the anterior-posterior measures and central left in the vertical measures at sagittal reformatting). In addition, it could be due to mistakes in measurements between the markers in this region, however, even if this was considered true, it seems not to have interfered because 4 significant differences represent 8 points that could be mistakenly measured among the 60 points measured, which represent 13.33% of error. Another question is: can the significant changes in the condylar positioning be translated into clinical problems? This is a question impossible to answer with the present study because there's no clinical data here, however, it is believed that because they are small changes and in a minority of the points studied, they probably will not be clinical problems.

Another point to discuss regards the occurrence of any metal-related artifact from the screw in the TMJ; and in the present study, probably because of the CBCT Image and the size of the screw, we didn't have a metal artifact that could hinder the analysis of the condylar position, as can be seen in Figures 4, 5 and 6.

Although some studies[26,27] advocated the maintenance of the preoperative condylar positioning in the postoperative period, another current issue is which is the desirable postoperative position of the mandibular condyle in orthognathic surgery[22]? The present study, for reasons already exposed above, is limited to answering this question though it seems to agree with Epker and Wylie[27] and Luhr[28], since the preoperative position of the mandibular condyles in most studied points are maintained (86.67%). It is lawful to believe that, in individuals with TMJ disorders in the preoperative time, the same preoperative condylar position may not be desirable for the postoperative time. As a result, in individuals free of TMJ disorders, the preoperative position seems to be desirable, and the use of the technique presented here might be useful.

In conclusion, bilateral sagittal split osteotomy of the mandible associated with the method of cephalometric data and surgical plan transfer changed the condylar positioning in a few specific points at the postoperative time.

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