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From the 2-dimensional analysis in the lateral radiograph to the 3-dimensional repositioning in maxillary surgery

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2-Dimensional Analysis in the Lateral Radiograph Significance of the Contour of the Lateral Surface of the Maxilla for Planning Maxillary Osteotomies

Introduction

Treatment planning for Le Fort I osteotomies usually consists of two dimensions, whereas, during actual surgery three dimensions must be considered. The contour of the lateral surface of the maxilla and its individual variations are not considered on the lateral radiograph, but this contour is important during surgery.

For planning surgery, on the lateral radiograph reference lines are drawn perpendicular to the occlusal plane from the tips of the canine and the mesiobuccal cusp of the first molar to the maxilla. By linking the most cranial points of these reference lines at the level of the nasal floor, the position of the osteotomy line can be determined (Fig. 1). According to these reference lines, the movement of the maxilla can be simulated in the sagittal and vertical dimensions (Fig. 2). During surgery the reference lines from the lateral radiograph are transferred to the lateral surface of the maxilla using a caliper.

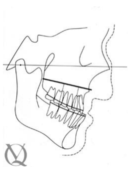

Fig. 1 Determination of the vertical reference lines and the position of the osteotomy cuts.

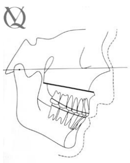

Fig. 2 Simulation of the maxillary movement along the planned osteotomy lines.

However, the lateral radiograph consists of two dimensions (Fig. 3), whereas, during surgery, three dimensions have to be considered (Fig. 4). The contour of the lateral surface of the maxilla and its individual regional variations are not reflected on the lateral radiograph.

Fig. 3 Two-dimensional planning on the lateral radiograph.

Fig. 4 Three-dimensional transfer on the skull.

Aim

In a first study, the influence of the third dimension on treatment planning was investigated.

Material and Methods

For this study, lateral radiographs were taken of 20 skulls (Fig. 5). An individual impression tray was fabricated from self-curing resin. Impressions were taken of the maxilla and maxillary teeth with this tray. Casts were fabricated, and cuts were made in the transverse vertical plane at the level of the tips of the canines and the mesiobuccal cusps of the first molars bilaterally (Fig. 6).

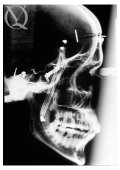

Fig. 5 Lateral radiograph of a studied skull.

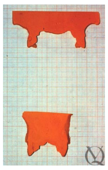

Fig. 6 Cuts of the casts at the level of the first molars (upper part) and the canines (lower part) bilaterally.

Contour lines of the lateral surfaces of the cuts in the areas of the molars (Fig. 7) and canines (Fig. 8) were drawn with a pencil on graph paper. The cuts were so orientated that a line linking the tips of the left and right tooth was parallel to a horizontal line on the graph paper.

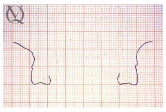

Fig. 7 Contour curves of the lateral surfaces of the cuts in the area of the molars.

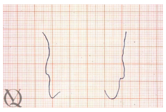

Fig. 8 Contour curves of the lateral surfaces of the cuts in the area of the canines.

Reference lines were drawn perpendicular to the occlusal plane from the tips of the canine and mesiobuccal cusp of the first molar to the maxilla. A desired height represented the length of reference line S, with end point P_1 (Fig. 9). The lengths of S_1 were chosen as tooth length (from the lateral radiograph) plus 2 mm and tooth length plus 4 mm. Therefore, an adequate distance from the tooth's roots was guaranteed during osteotomy, and different positions of osteotomy cuts could be examined.

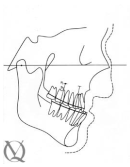

Fig. 9 Reference line S1 and end point P1 on a tracing of the lateral radiograph.

The reference line S_1 was transferred from the lateral radiograph to the contour lines using a caliper. On the contour lines the base point of S_1 was the tip of the reference tooth; the vertical direction of S_1 ended cranially at point P_1.S_1 was drawn a second time so that its base point ran through the tip of the tooth again, but the end point P_2 overlapped the contour line, which represented the lateral contour of the maxilla (Fig. 10a).

After S_1 was drawn on the contour line, S_1 and P_2 bar were projected onto the sagittal vertical plane. The desired heights of S_1, $P_{1\ bar}$, and P_1 could not be obtained (for geometric reasons) using a caliper due to the inclination of the lateral contour of the maxilla; only the height of point $P_{2\ bar}$, which lies more caudal than $P_{1\ bar}$ and P_1, could be determined. From the base point of S_1 (the tip of the examined tooth) and P_2 bar, a triangle was constructed with the base of S_1 and the sides of S_2 and S_3 (Fig. 10b).

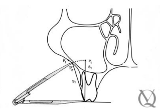

Fig. 10a Transfer of the planned reference lines and end points from the lateral radiograph to the contour lines.

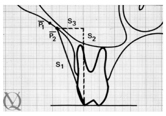

Fig. 10b Transfer of the planned reference lines and end points for measurement and calculation of the discrepancy S_2 minus S_1 .

The length of S_3 was measured, and the lengths of S_2 was calculated using the Pythagorean theorem ($S_2^2 + S_3^2 = S_1^2$). The difference of the lengths of the lines S_2 minus S_1 characterizes the discrepancy between the height of the points $P_{1\ bar}$ or P_1 on the lateral radiograph and the height of point $P_{2\ bar}$ on the contour line, in projection onto the sagittal vertical plane. The difference of S_2 minus S_1 is negative because $P_{2\ bar}$ is more caudal than $P_{1\ bar}$ or P_1. The discrepancies are noted in statistical evaluations (mean, standard deviation, minimum, maximum).

Results

The discrepancy of S_2 minus S_1 for the first molar averaged 0.3 to 1.3 mm, with a minimum of 0 mm and a maximum of 3.3 mm. The statistical evaluation shows severe discrepancies, which depend on the contour of the maxilla and the length of the examined reference lines – the longer the reference lines, the larger the differences (Fig. 11). The discrepancy of S_2 minus S_1 for the canine averaged 0.2 to 0.3 mm with a minimum of 0 mm and a maximum of 0.7 mm. Therefore, discrepancies are distinctly less than those for the first molar area (Fig. 12).

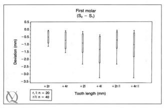

Fig. 11 Statistical evaluations of the discrepancy S2 minus S1 for the first molar.

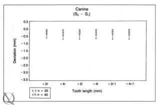

Fig. 12 Statistical evaluations of the discrepancy S2 minus S1 for the canine.

Discussion and Conclusions

Because of the anatomy of the lateral contour of the maxilla, reference lines for osteotomy cuts determined by the lateral radiograph could not be transferred onto the maxilla in a precise manner. It is not possible to exactly move the mobilized maxilla along the planned osteotomy cuts.

3-Dimensional Repositioning in Maxillary Surgery Techniques for Achieving Three-Dimensional Repositioning of the Maxilla in a Concept for Orthodontic-Surgical Treatment with Condylar Positioning

Introduction

The preoperatively planned and desired position of the maxillary dental arch often cannot be sufficiently achieved during model and actual surgery, and deviations especially in the sagittal and vertical dimensions are possible.

Objective

Problem during cast surgery

Ruler measurements at the base of the articulator above the dental arch and saw cuts along a planned osteotomy line appear to be too inaccurate methods for repositioning of the maxilla during model surgery (Fig. 13). Deviations of up to 3.8 mm sagittally and 5.5 mm vertically of the achieved from the planned position have been observed at the dental arches (ELLIS, 1990). These errors occur especially when the maxilla is moved in several dimensions simultaneously. If for instance the maxillary dental arch is moved to the anterior and its dorsal part is rotated upward, the incisal edge of an upper incisor moves posterior away from the planned position (Fig. 14).

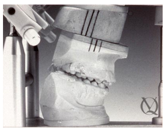

Fig. 13 Ruler measurements at the base of the articulator and saw cuts along a planned osteotomy line.

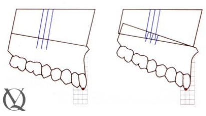

Fig. 14 If the maxillary dental arch is moved to the anterior and its dorsal part is rotated upward, the incisal edge of an upper incisor moves posterior away from the planned position.

Problem during actual surgery

Until now, it has been difficult to transfer the postoperative position of the maxillary dental arch from cast surgery to the intraoperative situation with sufficient accuracy. For the dental arches deviations of up to 6.0 mm sagittally and up to 15.0 mm vertically have been observed (McCANCE et al., 1992). These deviations can be explained as follows: After the maxilla is mobilized the planned dental relationship is obtained using a surgical splint. However, this dental relationship is only controlled in the sagittal and in the transverse dimensions (Fig. 15).

Since the maxillomandibular complex is rotated upward to the anterior and cranially maintaining centric relation, an additional control of the vertical position is necessary. This is usually performed by using a reference point on the maxilla below the osteotomy line, i.e. in the area which is moved during surgery, and a second reference point, which is located either intraorally on the maxilla above the osteotomy line or extraorally on the nose bone. Both approaches lead to a displacement of the lower reference point, especially in cases of large anterior advancements or transversal rotations of the maxilla after osteotomy, which makes the vertical placement difficult to control (Fig. 16). For these reasons the exact three-dimensional placement of the maxillary complex in relation to other skeletal structures during surgery was impossible.

Fig. 15 After the maxilla is mobilized the planned dental relationship is obtained using a surgical splint. However, this dental relationship is only controlled in the sagittal and in the transverse dimensions.

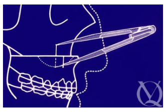

Fig. 16 Vertical control is usually performed by using a reference point on the maxilla below the osteotomy line, i.e. in the area which is moved during surgery, and a second reference point, which is located either intraorally on the maxilla above the osteotomy line.

Aim

To solve these problems, a new instrument and a new method in conjunction with the Goettingen concept for orthodontic-surgical treatment with condylar positioning were developed. These were applied during treatment, and the position of the maxilla before and after surgery was analyzed.

Material and Methods

Solution of the problem during cast surgery using the "model-repositioning instrument"

To solve this problem an appliance for controlled three-dimensional repositioning of the maxillary dental arch during cast surgery was developed (SCHWESTKA-POLLY et al., 1993).

After testing and modification, this appliance is now as "model-repositioning instrument" (SAM, Inc., Munich, Germany) in use for routine treatment. It permits simultaneous measurement of the position of three reference points at the dental arch of the meaxillary cast mounted in the articulator. These reference points are marked on the edge of a maxillary incisor and at the mesiobuccal cusps of the first or second molars bilaterally, and their positions are registered using measuring pins. The measuring pins can be moved in a three-dimensional orthogonal coordinate system (Fig. 17).

The appliance allows an exact transfer of the position of the dental arch from one position to the next. During repositioning the cast is fixed by the tips of the three measuring pins. For this procedure no osteotomy lines have to be drawn on the base of the cast. Additionally, the application of the "model-repositioning instrument" permits control and adjustment of the position of the maxilla in relation to the mandible (Fig. 18).

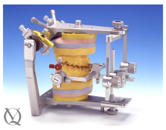

Fig. 17 Model-repositioning instrument with the maxilla in the preoperative position.

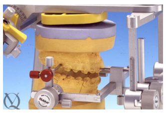

Fig. 18 The maxillary cast is loosened from its base. The tips of the measuring pins are adjusted to the postoperative position and hold the cast.

Solution of the problem during actual surgery with the "three-dimensional double splint method"

To solve the problem of three-dimensional positioning of the maxilla during actual surgery, the "three-dimensional double splint method" was developed (SCHWESTKA et al., 1990). Firstly, the sagittal and transversal placement of the maxillary arch is thereby given by the surgical splint. Secondly, the vertical placement is based on the fact that the vertical position of the mandible in relation to a reference plane above the osteotomy line can be exactly reproduced during cast and actual surgery. By reproducing a defined mandibular position, the maxilla can be placed three-dimensionally with the aid of new splint technologies.

Splint fabrication
A reference system is chosen for fabrication of these splints in the articulator, which is especially reproducible in the vertical dimension. This reference system consists of the upper part of the articulator, the condylar boxes, the lower part of the articulator, and the incisal pin . For preparation of the splints the bite is opened to the same extent in the preoperative and postoperative articulators, in both cases as little as possible. The length of the incisal pin remains constant for the preoperative and postoperative situation. This way it is possible to fabricate a surgical splint for the postoperative situation which represents the planned movements of the maxilla in all three dimensions.

The first splint (indicated here in blue color) is prepared in the articulator representing the preoperative situation. It is applied during surgery for positioning the maxilla and the condyles in centric relation before osteotomy (Fig. 19).

The second splint (indicated here in blue-yellow color) is fabricated for three-dimensionally controlled positioning of the maxilla in the postoperative situation. If for instance it is desired to move the maxilla upward, the second splint will be vertically enlarged in the corresponding way (Fig. 20).

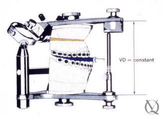

Fig. 19 Principle of fabrication of the surgical splints in the articulator according to the three-dimensional double splint method. The vertical dimension, e.g. the length of the incisal pin, is the same in the pre- and postoperative situations.

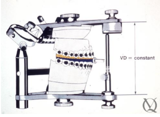

Fig. 20 The second splint represents the three-dimensionally controlled new position of the maxilla in the postoperative situation.

Surgical procedure

The three-dimensional placement of the maxilla during surgery is especially based on the fact, that the vertical position of the mandible in relation to the skull above the osteotomy line can exactly be reproduced in the preoperative situation as well as in the postoperative situation: The centric condylar position is transferred from the articulator to the patient using the first surgical splint (here blue colored) and temporary maxillomandibular fixation. Subsequently a reference point, e.g. a drill hole, on the bony structure of the maxilla above the osteotomy line is defined and its vertical distance to a reference point on the mandible, e.g. on a bicuspid bracket, is measured by a caliper. The initially defined distance is arbitrary and depends only on anatomical structures (Fig. 21).

Centric condylar position is ensured by two positioning plates (Fig. 21a), e.g. Mini-fixation plate system from LUHR osteosynthesis system, Leibinger, Inc., Freiburg, Germany (LUHR, 1985; KUBEIN et al., 1987; LUHR, 1989, LUHR et al., 1992).

After mobilizing the maxillary complex the second surgical splint (here yellow colored) is inserted, which represents the new maxillary position. Temporary maxillomandibular fixation is performed again and the maxillomandibular complex is rotated upward to the anterior and cranially. The vertical dimension is controlled by the caliper. The distance in the caliper must be the same as in the preoperative situation (Fig. 22). The two positioning plates are reinserted again (Fig. 22a). So it is possible to reposition the maxilla three-dimensionally controlled with condylar positioning. After osteosynthesis (Mini-fixation plate system or Panfix-fixation plate system from LUHR osteosynthesis system, Leibinger Inc., Freiburg, Germany) the second surgical splint is removed and the mandible rotates into the new centric occlusion without any postoperative intermaxillary fixation.

A postoperative splint in combination with light intermaxillary guiding elastics is inserted.

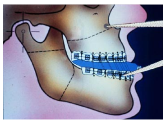

Fig. 21 During surgery the vertical position of the mandible in relation to the skull above the osteotomy line can exactly be reproduced in the preoperative situation as well as in the postoperative situation. This is controlled by a caliper.

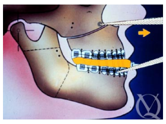

Fig. 22 The vertical dimension is controlled by the caliper again. The distance in the caliper must be the same as in the preoperative situation.

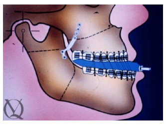

Fig. 21a Centric condylar position is ensured by two positioning plate.

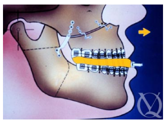

Fig. 22a The two positioning plates are reinserted again.

Analysis

In 20 adult patients, the new instrument and method were applied, and the position of the maxilla before and after surgery was analyzed. Each patient had been treated orthodontic-surgically by means of Le Fort I osteotomy alone or in combination with a sagittal split osteotomy. The movements of three reference points in cast surgery were compared with the movements during actual surgery.

In each patient the position of the maxilla was obtained from lateral radiographs which were taken preoperatively and postoperatively for routine diagnosis purposes. Three reference points in the maxillary dental arch were selected for measurements: at the first right incisor (R 11), the first right molar (R 16), and the second left molar (R 27). They were marked by using three metal balls (diameter 2 mm) which had previously been inserted in the upper surface of the first surgical splint (Fig. 23). Both preoperative and postoperative lateral radiographs were taken with the splint being inserted in the mouth of the patient (Fig. 23a).

For the analysis of the radiographs the computer program WinCeph 4.0 (Compudent, Inc., Koblenz, Germany) was used. After the tracings of the preoperative and postoperative radiographs were superimposed anatomically with respect to the anterior base of the skull, the achieved displacements of the reference points were measured in the vertical and sagittal dimensions with respect to the hinge axis-infraorbital plane (CR-Or) as reference plane (Fig. 24).

The real movement measured on the tracings of the lateral radiograph and the planned movements from cast surgery were compared and analyzed using the statistical package STATISTICA (StatSoft, Inc., Tulsa, USA).

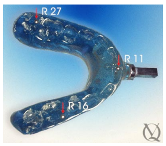

Fig. 23 First surgical splint with three metal balls reference poinsts (R 11, R 16, R 27) on the upper surface.

Fig. 23a Lateral radiographs before and after surgery with the first surgical splint in place.

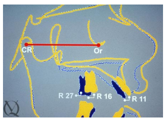

Fig. 24 Superimposition of the lateral radiograph tracings and measurement of the movements of reference points R 11, R 16, and R 27; blue colored = preoperative position, yellow colored = postoperative position; CR = center of rotation, Or = Orbitale.

Results

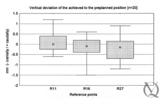

Fig. 25 Deviations of the achieved position of reference points R 11, R 16, and R 27 from the planned position in the vertical dimension.

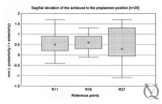

Fig. 26 Deviations of the achieved position of reference points R 11, R 16, and R 27 from the planned position in the sagittal dimension.

Vertical dimension

The vertical deviation of the achieved from the planned position of the maxillary complex with reference points R 11, R 16, and R 27 did not exceed 1.5 mm (Fig. 18).

Sagittal dimension

For the sagittal dimension, the values for the reference points R 11, R 16, and R 27 differed by at most 1.7 mm between the achieved and the planned position (Fig. 19).

Alltogether the results show that an orthodontic-surgical treatment of the maxillary complex using the "model-repositioning instrument" and based on the "three-dimensional double splint method" permits an accuracy of ± 1 mm in the vertical and sagittal dimensions for the achieved position of the maxilla.

Discussion and Conclusions

Using the new tools, the "model-repositioning instrument" and the "three-dimensional double splint method", the planned position of the maxillary dental arch could be transferred from cast surgery to actual surgery with an accuracy of ± 1 mm sagittally and vertically. Thus, the application of the Goettingen concept for three-dimensional repositioning of the maxilla results in an improvement of accuracy compared with other methods. Furthermore, it is easier to handle and less time-consuming during cast and actual surgery than other procedures.

Bibliography

- McCance AM, Moss JP, James DR: Le Fort I maxillary osteotomy: is it possible to accurately produce planned pre-operative movements? Br J Oral Maxillofacial Surg 1992, 30, pp. 369-376.
- Ellis E III: Accuracy of model surgery: evaluation of an old technique and introduction of a new one. J Oral Maxillofac Surg 1990, 48, pp. 1161- 1167.
- Kubein D, Luhr HG, Jäger A, Schauer H-W, von Ehrlich V: Diagnostik der Relation der Kiefergelenke zur Okklusion. Intraoperatives Kontrollverfahren zur Optimierung kieferorthopädisch-chirurgischer Eingriffe in Verbindung mit der Plattenosteosynthese. Fortschr Kieferorthop 1987, 48, pp. 267-275.
- Luhr HG: Skelettverlagernde Operationen zur Harmonisierung des Gesichtsprofils - Probleme der stabilen Fixation von Osteotomiesegmenten. In: Pfeifer G (Hrsg). Die Ästhetik von Form und Funktion in der plastischen und Wiederherstellungschirurgie. Berlin: Springer, 1985, pp. 87-92.
- Luhr HG: The significance of condylar position using rigid fixation in orthognathic surgery. Clin Plast Surg 1989, 16, pp. 147-156.
- Luhr HG, Schwestka R, Kubein-Meesenburg D: Intraoperative control of condylar position in maxillary osteotomies with rigid skeletal fixation. In: Bell Wh (ed). Modern practice in orthognathic and reconstructive surgery. Philadelphia: Saunders, 1992, pp. 628-639.
- Schwestka R, Engelke D, Kubein-Meesenburg D: Condylar position control during maxillary surgery: the condylar positioning appliance and three-dimensional double splint method. Int J Adult Orthod Orthognath Surg 1990, 5, pp. 161-165.
- Schwestka-Polly R, Roese D, Kuhnt D, Hille K-H: Application of the model-positioning appliance for three-dimensional positioning of the maxilla in cast surgery. Int J Adult Orthod Orthognath Surg 1993, 8, pp.25-31.

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