Accuracy of maxillary advancement during bimaxillary operations using a CAD/CAM generated splint

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Introduction:

Computer assisted 3D planning is used more and more in orthognathic surgery. Transfer of the virtual planning into the operation site is well established for the transversal and sagittal position by using CAD/CAM generated splints. The adjustment of the vertical position is still more difficult due to the non-fixed mandibular reference. As such, fixation of the mandible to the zygoma region using osteosynthesis plates and subsequent use as a reference is a possible solution. The aim of our study was to evaluate the precision of maxillary movement when using CAD/CAM splints combined with a temporary fixation of the mandible.

Method:

10 mandibulo-maxillary operations were virtually planned by using the software ProPlan CMF © (Materialise, Belgium). First the primary CT-scan was segmented followed by performing a virtual Le-Fort-I-osteotomy and digital maxillary advancement. (Fig. 1a,b and 2a,b).
For the transfer of the planned position into the operation site stereolithographic splints were generated and used during the surgical procedure to reposition the maxilla (Fig. 3)
The dental casts of the upper and lower jaw were digitally scanned and overlaid with the CT scan. (Fig. 4, 5) As a result a precise intraoral fitting of the CAD/CAM generated splint on the patient dentition could be achieved (Fig. 6).
The primary position of the mandible in relation to the maxilla was fixed during the 3D-Imaging (Fig. 7, 8) where the patient carried a blue conventional primary splint in habitual occlusion (Fig. 9). During the operation the mandible was positioned using this splint and fixed to the maxilla with osteosynthesis plates from the ramus mandibularis to the zygoma region on each side (Fig. 10 a,b)

Fig. 1a and 2a: pre-operative primary findings

Fig. 1b and 2b: planned maxilla movement

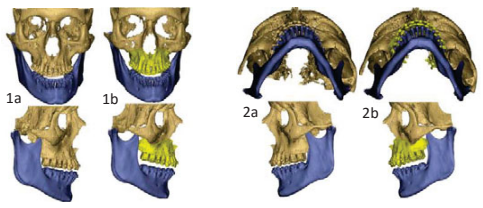


Fig.3: CAD/Cam splint


Fig.4: scanned plaster cast with splint

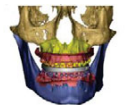
Fig.5: overlay of scan onto the planned maxilla movement


Fig.6 Splint and models

Primary Results

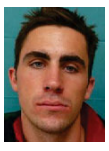

Fig.7: pre-operative Enface-photograph

Fig.8: pre-operative natural occlusion

Fixation of the Mandible


Fig.9: primary splint with articulator


Fig.10a and b: mandible fixated from ramus to the zygoma by fixation plates and primary splint

After removing the ramus fixation plates and the primary splint the Le-Fort-I-osteotomy and the mobilization of the maxilla was done. This was followed by mandibulomaxillary fixation with the positioned CAD/CAM generated splint (Fig. 11, 12). Consequently the planned transversal and sagittal movement was transferred to the operational site.
To transfer the vertical positioning, the ramus fixation plates were placed at both sides of the ramus of the mandible. Then the mandibulomaxillary complex (positioned by the CAD/CAM generated splint) was moved cranial, until both fixation plates could be aligned and re-fixated in the original holes cranial of the Le-Fort-I osteotomy line (Fig. 13). The definitive osteosynthesis followed with miniplates paranasal and after removing the ramus fixation plates in the zygoma region (Fig. 14)
After bilateral sagittal split osteotomy of the mandible the final occlusion was defined by a conventional dental lab produced splint and osteosynthesis with semi rigid splitfix plates (Fig 15-17).

Maxillary Positioning


Fig.11: CAD/CAM-splint with articulator


Fig.12: fixation by CAD/CAM Splint


Fig.13: fixed maxilla position with CAD/CAM splint and ramus fixation plates. Definitve paranasal osteosynthesis already in situ.

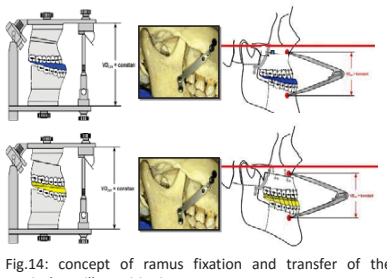
Fig.14: concept of ramus fixation and transfer of the vertical maxilla positioning

Positioning of the Mandible


Fig.15: lab produced splint in final occlusion with articulator


Fig.16: lab produced splint in final occlusion intraoperative


Fig.17: post OP results

To evaluate the accuracy of the transfer into the operational site image fusion of the 3 dimensional planned position (green) and the post-operative result CT-Scan (blue) was performed.
The post-operative dataset (blue) was segmented and overlaid with the primary (red) and the planning data set (green) using a semi-automatic registration method in the unchanged zygoma/-arch region (Fig. 18). All three datasets were positioned in the same coordinate system.
Five occlusal landmarks were defined on the scanned digital dental impressions and marked in the virtual model (Fig. 19: incisor point, tip of the canine teeth and mesio-buccal cusp of the first molars).
The marked digital impression models were overlaid on each of the 3 data-set. Afterwards the derivation between the points was measured followed by the evaluation of the variance of the results in x, y and z-axis in mm. (Fig. 20 - 24b).

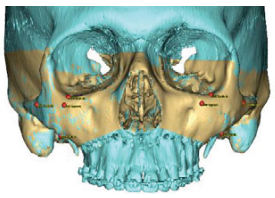
Fig.18: Image fusion of primary CT with post OP CT overlaid in the area of the unchanged zygoma region

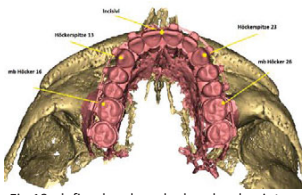
Fig.19: defined and marked occlusal points. Incisor point, tip of the canine teeth and mesio-buccal cusp of the first molars

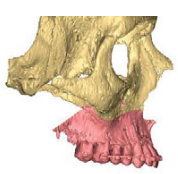
Fig.20: segmented maxilla in the pre operative CT (red)

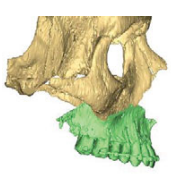
Fig.21: planned maxilla movement (green)

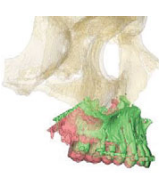
Fig.22: Fusion original maxilla with planned moved maxilla

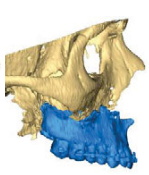
Fig.23: segmented maxilla in the post OP CT

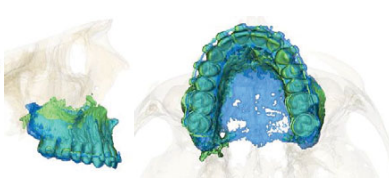
Fig.24a und b: Fusion of planning and post-op result in sagittal and vertical plane

Results:

The median deviation over all points and teeth was 0.76mm. Across the three defined axes, there was a median deviation of 0.97mm in the transversal, 0.62mm in the sagittal and 1.05mm in the vertical plane. It appears that there is a more precise transfer of the planned sagittal position into reality being possible by using our method, than in the other planes (without significance) (Fig. 25 and Tab. 1).
During our analysis there was no significant difference between the defined groups incisor point, tip of the canine and mesiobuccal tip of the first molar by relative high precision.
The maximal deviation between planning and the operation results was 2.03mm in the transversal, 2.23mm in the sagittal and 2.58mm in the vertical plan.

Deviation of all teeth in the three axis

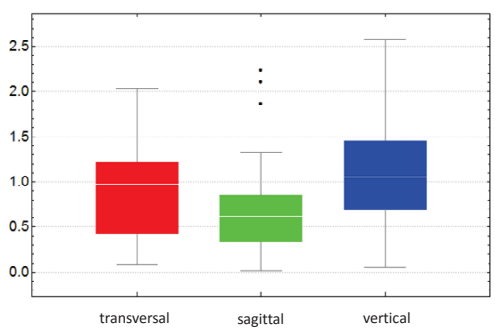

Fig. 25

All Teeth:	Q25	Median	Q75	Max
transversal	0,45	0,97	1,31	2,03
sagittal	0,44	0,62	0,90	2,23
vertical	0,78	1,05	1,29	2,58

Tab. 1

Discussion and Conclusion:

The method used in our hospital is shown to be very precise overall with a good clinical applicability. However, by using the mandible fixation for the vertical reference the operation time is prolonged by approximately 30-45 minutes.
Alternatively, waferless positioning of the maxilla can be achieved by patient specific CAD/CAM guides and CAD/CAM plates. First results of this method seem to be very promising by noticeable reduction of the operation time and increased precision.

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The authors disclose that they have no conflict of interest.