From the results of this study, the importance of the image diagnosis was reconfirmed before the implant installation for the MT region, the extraction of the third molar, and Le Fort 1 osteotomy.

Asymmetric healing formation of a calcium phosphate biomaterial graft donated to a mandibular cystic bone defect

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Keywords Mandibular cyst · Biomaterial graft · Post-operative healing · Medical visualization

Purpose

Cystic or cyst-like lesions may occur in skeletal organs all over the human body, so in the femur, the humerus, or the mandible. Generally, they appear as kind of cavities within the bone, filled with fluid or mushy substance. Mostly benign, they can also turn to malign. Often they are painless for the patients, but continuously growing. Therefore, they have to be—usually surgically—removed.

Due to their weakening effect on the skeletal tissue, these lesions are certainly affecting the organ's structural behaviour. Usually, they have decisive influence on the patients' attitudes, e. g. walking or chewing. Thereby, according to Wolff's law, they are suggested to seriously influence the constitution of the skeletal organ as a whole. Once these lesions are treated with some biomaterial graft, the overall situation of the skeletal organ is again changed, and further significant influence on the organ's condition is expected.

It is known from micromechanics research and macroscopic biomechanics that the local distribution and also the 3D-profile over the whole organ based on Hounsfield units (HU) from CT-data gives significant insight about the changes of the skeletal organ during treatment. Therefore, we applied a refined computer assisted evaluation scheme to a series of pre- and post-operative medical CT-data of a clinical case of a mandibular cystic lesion treated with some calcium phosphate biomaterial graft.

Methods

We considered a case of a partially edentulous atrophic mandible (female, 41 Y) with an extended radicular odontogenic cyst of the alveolar ridge. The lesion was surgically removed without complications. The cystic cavity was filled, by about 70 volume %, with a Ca10 (PO4)6(OH)2 calcium phosphate biomaterial graft provided as porous granules, with mean diameters of 1–2 mm. The granules are inhomogeneous, but without any inherent anisotropic structures.

High resolution CT-data (NIM SLR QR-DVT 9000, Italy) with comparable scanning conditions were acquired, pre- and directly post-operatively, and two follow ups at 3 respectively 9 months after surgery. All data sets were with 512 × 512 image matrix, 0.29 mm × 0.29 mm pixel spacing, and slice thickness between 0.157 and 1 mm.

For comparable analysis, all CT data sets were rigidly registered to the one with the highest resolution and resampled to identical dimensions. The mandibular bone (without teeth) and the cystic region, with some safety margin around, were segmented from the CT-data and isolated from the remaining voxels. For qualitative analysis, the voxels of the concerned regions were subjected to highly transparent direct volume rendering with a logarithmic transfer function using a physical colour scale (dark blue—light blue—green—yellow—orange red, in ascending order). This transfer function was chosen for easy identification of voxels with elevated Hounsfield values. For quantitative confirmation, we analyzed the pre- and post-operative development via histograms of the cystic region as well as of the mandibular bone.

Results

Analysis of the bone defect and its regeneration:

By visualization of the defect region as a whole, the biomaterial graft showed an inhomogeneous and irregular appearance with buccally elevated HU values. This effect was observed directly post-operatively and endorsed between month 3 and 9 post-surgically.

For investigation of the inner consistence of the biomaterial graft, an axial cut across the lesion revealed a highly asymmetric distribution, again with buccally higher HU-values rather than lingually, possibly indicating the growth of a new cortical shell (Fig. 1). As before, the effect could already be discerned for the directly post-operative data, and was amplified until month 9. Interestingly, higher concentrations were observed frontally rather than dorsally.

These observations were quantitatively confirmed by histogram analysis (Fig. 2). Pre-operatively, we found some peak for small Hounsfield-values flattened for all post-op data probably due to cystic fluid. Histogram portions related to HU-values between 200 and 1,100, maybe referring to the original biomaterial, are nearly identical for all post-operative data. Interestingly, the number of voxels with high HU-values, notably between 1,200 and 1,800, and probably referring to cortical bone, are nearly identical for the directly post-operative data and month 3, but definitely increased for month 9. This observation suggests that significant new bone formation may have taken place in this time.

Analysis of the mandibular bone:

For investigation of the influence of the lesion as well as of the biomaterial graft on the skeletal organ, we applied a corresponding analysis to pre- and post-operative HU-profiles of the remaining mandibular tissue, but excluded the defect region.

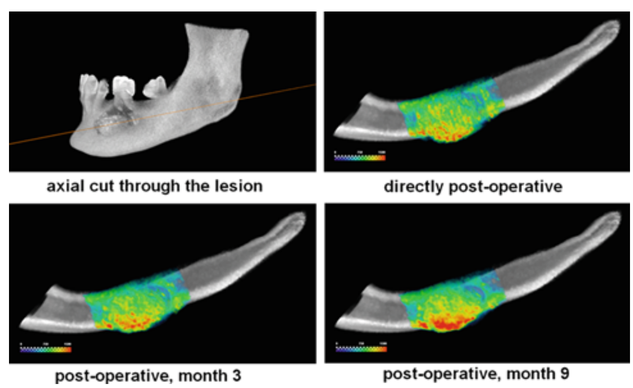

Fig. 1 Axially clipped visualization of post-surgical development of the HU-profile within the biomaterial graft

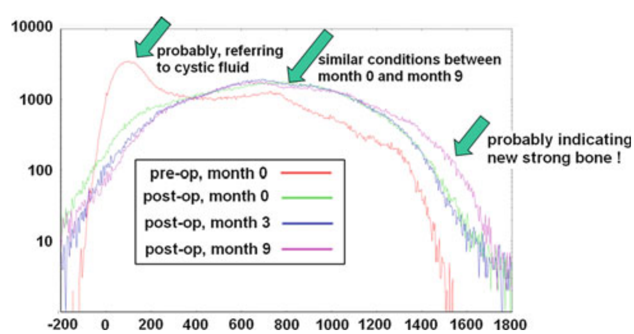

Fig. 2 Histogram analysis of the cystic region, linear representation of HU values, logarithmic representation of counts (ordinates)

A qualitative analysis of only the pre-operative situation showed an asymmetric distribution with higher HU-values at the affected side (with lesion) of the alveolar ridge rather than at the non-affected side. Even more remarkably, we found an asymmetric distribution at the chin, with elevated values at the affected side. A qualitative comparison of pre- and post-operative HU-profiles showed a continuous decrease of high HU-values from the pre-operative situation to the final follow up, which was confirmed by quantitative histogram analysis. As high HU-values stand for strong cortical bone this finding presumably indicates rapidly progressing atrophy.

Conclusion

We observed an inhomogeneous post-surgical development within the biomaterial graft indicating new bone formation during healing period, especially between month 3 and 9 after surgery. Additionally, we found an anisotropic respectively asymmetric distribution within the biomaterial graft, possibly inter alia representing the growth of a new cortical shell. For the mandibular bone, we could state, on the one hand, some influence of the lesion as well as of the biomaterial graft on the organ's skeletal constitution, and on the other hand, strong post-surgical decrease of HU-values, probably indicating rapidly progressing atrophy.

As 3D-profiles of Hounsfield-units are related to the distribution of elastic coefficients over the organ, and thereby directly referring to bone stability and quality, these profiles are of immediate clinical relevance. Next step will be biomechanical finite element simulation based on these data respecting the inhomogeneous and anisotropic distribution of the mandibular bone.

Acknowledgments

This work was supported under the Theme FP7-2008-SME-1 of the 7th Framework Programme of the European Commission, Grant no. 232164, BIO-CT-EXPLOIT.

Correlation between facial morphology change and mandibular movement change following orthognathic surgery

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Keywords Orthognathic surgery · Facial morphology · Mandibular movement · 3-Dimensional measurement

Purpose

Orthognathic surgery is widely performed to improve facial esthetics and masticatory function including mandibular movement. It has been reported that there was a correlation between the mandibular movement range and facial morphology such as ramus inclination and mandibular length. There were studies on the relationship between the change in mandibular movement and morphological change after surgery [1, 2]. However, no studies was performed based on 3-dimensional analysis of mandibular movement and facial morphology. The purpose of this study was to analyze the correlation between changes in 3-dimensional mandibular movement and 3-dimensional facial morphology change before and after orthognathic surgery.

Materials and methods

The mandibular movement data were acquired from 21 subjects (9 males and 12 females) underwent orthognathic surgery pre- and post-operatively. Previously developed mandibular movement tracking and simulation system was used to acquire 3-dimensional mandibular movement of the subjects before and after surgery. Three-dimensional maximum linear movements of the 4 selected points (bilateral condylions, infradentale, and pogonion) were measured while the subjects were performing voluntary maximum mouth opening and closing movement.

Among 30 maximum mouth opening movement data, 5 were selected for each subject. Sequential linear displacements of the selected points were calculated 3-dimensionally and maximum mandibular opening (MMO) values of the designated points were acquired for each maximum mouth opening. Mean MMO values were calculated for each point pre- and post-operatively. Three-dimensional facial morphology values were also measured from CT data before and after surgery. Length and angular values were measured 3-dimensionally based on the designated landmarks.

Mandibular deviation was decided and bilaterally existing values were divided into 2 groups, the deviated side (DS) and counter-deviated side (CDS) group. Quantitative changes in the mandibular movement and facial morphology values were calculated and Pearson's correlation coefficients were computed to analyze the correlation between changes in the mandibular movement and facial morphology values.

Results

Most of the MMO values were decreased; however, there was no significance. Only infradentale movement in x-axis showed significant decrease after surgery. On the other hand, bilateral condylar movements were increased in x- and z-axis with no significance although 3-dimensional condylar movements were increased. All morphological values were decreased after surgery except for ANB angle. There were significant decrease in mandibular length on DS and ramus length on CDS. According to the result of correlation coefficient calculation, several morphological changes showed correlation with the mandibular movement change. Total facial height (Nasion-Menton) and lower facial height (ANS-Menton) were negatively correlated with condylar movement change in 3-dimension and y-axis. The movement change of condyle in z-axis of DS was positively correlated with ramus length change of CDS. Movement change of infradentale in x-axis was correlated with ramus length of CDS. Upper facial height was negatively correlated with movement change of infradentale and pogonion in x-axis. ANB angle showed correlation with change of the pogonion movement in z-axis.

Conclusion

The amounts of change in morphological values introduced from the orthognathic surgery were associated with the changes in mandibular movement. It is expected that 3-dimensional analysis provide more useful information on the relationship between mandibular movement change and facial morphology change.

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