Patient-tailored fixation plate for accurate 3D positioning in corrective osteotomy of the distal radius

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A bone fracture may lead to malunion of bone segments, which gives discomfort to the patient and may lead to chronic pain, reduced range of motion, reduced grip strength and finally to early osteoarthritis. A treatment option to realign the bone segments is a corrective osteotomy \cite{4}. In this procedure the surgeon tries to improve alignment by cutting the bone at, or near, the fracture location and by fixing the bone segments in an improved position, using a plate and screws. Standard corrective osteotomy of the distal radius is most often planned using two orthogonal radiographs to find correction parameters for restoring the radial inclination, palmar tilt and ulnar variance \cite{3} to normal. However, 2D imaging techniques hide rotations about the bone axis \cite{5} and may therefore cause a misinterpretation of the correction parameters \cite{1}. Moreover, three-dimensional positioning is very complex and difficult to plan, perform and evaluate using standard 2-D fluoroscopy imaging \cite{2}.

We present a new technique that uses preoperative 3-D imaging techniques to plan positioning and to design a patient-tailored fixation plate that only fits in one way and realigns the bone segments as planned in six degrees of freedom (three translations of the distal segment along three orthogonal axes of a Cartesian coordinate system, and three rotations about these axes). The procedure uses a surgical guide that snugly fits the bone geometry and allows predrilling the bone at specified positions, and cutting the bone through a slit at the preoperatively planned location. The patient-tailored plate fits the same bone geometry and uses the predrilled holes for screw fixation. The method is evaluated experimentally using artificial bones and renders realignment highly accurate and very reproducible ($d_{\text{err}} < 1.2 \pm 0.8$ mm and $\varphi_{\text{err}} < 1.8 \pm 2.1^\circ$). In addition, the new method is evaluated clinically ($n=1$) and results in accurate positioning ($d_{\text{err}} \leq 1.0$ mm and $\varphi_{\text{err}} \leq 2.6^\circ$).

Besides using a patient-tailored plate for corrective distal radius osteotomy, the method may be of interest for corrective osteotomy of other long bones, mandibular reconstruction and clavicular reconstruction as well. In all of these cases the contralateral side can equally be used as reference for reconstruction of the affected side. Even if a healthy reference is missing, the surgeon can plan the position of one (distal) bone segment with respect to another (proximal) bone segment in a manual fashion, e.g., guided by surrounding anatomy. A patient-tailored plate can thus generally be used to fixate bone segments in a planned position.
The two-step method of predrilling and cutting using a surgical guide, followed by the utilization of a patient-tailored plate for fixation and accurate 3D positioning at the same time, seems very easy to utilize during surgery, since it does not require complex navigation, robotic equipment or tracking tools. Custom treatment with a patient-tailored plate may reduce the reoperation rate, since repositioning is likely to be better than conventional malunion treatment using 2D imaging techniques and a standard anatomical plate. The patient-tailored plating technology is expected to have a great impact on future corrective osteotomy surgery.

References