A NEW PARADIGM FOR AUGMENTATION DECISION MAKING IN SPINAL POSTERIOR FIXATION

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Introduction

Bone augmentation is a preventive action for pedicular fixation mechanical failure. There is no documented gold standard for decision making. The maximum axial load before bone anchorage failure known as Fmax(N) is a widely admitted performance comparator for pedicular screw systems. Symmetrically, a patient's pedicle anchorage is assessable with Fmax for a given screw. Academic qCT Fmax-based models accuracy culminates at ρ=0.730 [1]. PedicleForce (*Fig.1*) proposes a new patient-specific Fmax-based ruler for screw augmentation indication combining accuracy and reliability.

Material & Methods

A previous study provided from ten donors each T12, L4 and L5, CT, DEXA and 6.1×40mm screw experimental Fmax (FmaxExp) with a medio-lateral trajectory and insertion precision <1mm [2]. Vertebrae and experimental trajectories registration in the CT coordinate reference was performed by PedicleForce. The PedicleForce linear multivariable model (Python, Mevislab, R) matched experimental trajectories, FmaxExp, screw parameters, bone micro-structure and CT markers assessed by the Leave-One-Out-Cross-Validation (LOOCV) method. The pullout plastic displacement corresponding to 50% of FmaxExp (FmaxExp50) was determined on the experimental force/displacement curves. For each cadaveric pedicle, PedicleForce simulated breachless trajectories and Fmax (Fig.1). The lowest to highest Fmax variation (MaxVSMin) and the lowest Fmax to FmaxExp variation FmaxExpVSMin were calculated. The distance from the experimental to the baseline trajectory was determined (ExpToMin).

Results

Donors mean age was 81.8±7.8y. DEXA: -2.6±1.6SD, [-4.4;.6]. FmaxExp: 477±419N, [104;1614]. Experimental insertion accuracy was <1mm. Registration repeatability incertitude was <1%. Fmax prediction error: 73.1N; accuracy (R^2): .99 All p-values <0.001. Simulated trajectories per pedicle: 171±131, [3;507]. Fmax50d: 1,8±0,4mm, [1,1;3,3]. ExpToMin: 2.0±1.8mm, [0.0;7.4], median 1.4. MinVSTarget: -.15±.13, [-0;-.52]. MinVSMax: -.36±.32, [-.03;-2,61].

Discussion

Mechanically demanding procedure like derotation can easily damage the pedicle construct leading to pseudarthrosis, loosening and mechanical failure: a supplementary 1,8mm plastic extraction was enough to halve FmaxExp. Such a tiny displacement is hardly noticeable and avoidable during the procedure which emphasizes the need for a pedicle-specific Fmax preventive frailty assessment for preventive augmentation.

For each pedicle, PedicleForce differentiated between bone quality, osteophytis, fibrosis, vertebra geometry and trabecular bone networks.

Its R^2=.99 competes with reference µCT based models [2]. Surgeon's settings are limited to the patient's CT upload.

Current surgical insertion methods do no guarantee a millimetric or less accuracy causing an unpredictability for planning. Trajectories simulation illustrates that a 2mm drift from the experimental canonical trajectories, MinVSTarget, resulted on average in -15% strength. MinVSMax shows a large trajectories strength scope of 36% in average.

In response, the PedicleForce Fmax-G indicator (G stands for guaranteed) is the baseline strength indicator covering from the peroperative screw trajectory uncertainty. Fmax-G is the minimum pedicle-specific simulated Fmax.

The Fmax-G interpretation for global or selective augmentation can be achieved in absolute values (N or eq Kg) and in respect with the expected operative forces literature [3].

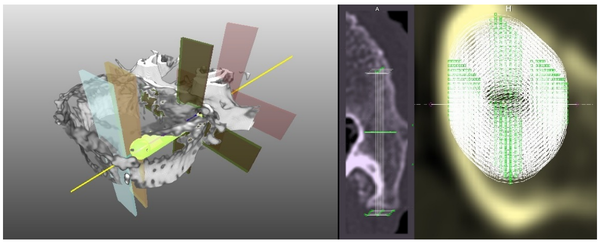

Figure 1: PedicleForce Trajectories Breachless Quality Control interface

References

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2. Van den Abbeel et al., Comput Methods Biomech Biomed Engin. 21:13-21, 2018.
3. Alingalan et Al., Clinical Biomechanics 28:122–128, 2013.