THE CLIVUS RECONSTRUCTION: A NOVEL METHOD FOR IDENTIFYING THE OPTIMAL SET OF SCAFFOLDS

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Introduction

In the last two decades, endoscopic transnasal surgery has revolutionized the treatment of sinonasal and skull base diseases by providing access to deep regions of the skull base, such as the clivus, with minimal brain retraction and cranial nerve manipulation. However, skull base reconstruction remains a challenge[1], which can be addressed through 3D printing of patient-specific scaffolds. Identifying a limited number of clivus variations could offer an alternative to creating tailored scaffolds, reducing production costs and waiting times.

Objectives This study aims to propose a new method to identify a small number of adaptable clivus prototypes that require minimal reduction of their shape measures. Surgeons can quickly adjust these prototypes in the operatory room by reducing key measurements by a maximum of 1 mm.

Methods and Results: Four clivus measurements identified by neurosurgeons as determinant of its shape were evaluated on 163 MR Images (MRI) belonging to Italian adults with unknown age and sex collected at Ospedale Civile of Brescia (Italy). These measures are distributed as a multivariate normal random variable. Our interest lies in the hyper-ellipsoid defined by the multivariate normal distribution with mean and covariance matrix estimated from the sample, which encloses 95% of the data. For computational efficiency, this hyper-ellipsoid was approximated by a set of points on a regular grid with a step size of 0.15 mm. The clivus prototypes were represented by hyper-cubes with side 1 mm and centres c_i. We used the Hooke-Jeeves algorithm[2], an optimization procedure designed for non-smooth functions, to calculate the optimal placement of *k* hyper-cubes for maximum coverage of the hyper-ellipsoid. The number of prototypes *k* was determined based on ensuring a coverage of the hyper-ellipsoid greater than 99%. For each patient, a single prototype is assigned, chosen to minimize the amount of reduction across the four dimensions required by the surgeon in the operatory room.

Conclusions The described procedure has the potential to be easily extended to other bone prototypes and could serve as a valuable tool for biomedical engineers in the design of prostheses.

References

1. Mattavelli, D. et al. Additive Manufacturing for Personalized Skull Base Reconstruction in Endoscopic Transclival Surgery: A Proof-of-Concept Study. World Neurosurg 155, e439–e452 (2021).
2. Conn A.R., Scheinberg K., Vicente L.N. Introduction to Derivative-Free Optimization. https://www.studmed.ru/conn-ar-scheinberg-k-vicente-ln-introduction-to-derivative-free-optimization_db908730410.html.