Primary Stability of Dental Implants in the Human Jawbone

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Introduction

The primary stability of dental implants is a crucial indicator of their expected performance and longevity. To date, many studies have explored the factors influencing primary stability. However, most publications on the subject use bone from other body parts, bone of animal origin (porcine, bovine) or polyurethane foam. Furthermore, the most common approach is to employ clinically used indirect measurements of primary stability like insertion torque (IT) or resonance frequency analysis (RFA). The aim of this study is to investigate the properties of human jawbone and quantify the primary stability of dental implants in anatomical implantation sites.

Materials and Methods

Implants with different diameters (3.5, 4.0 mm) were inserted into three sets of matching maxilla and mandibula according to the manufacturer's implantation guide. After pilot drilling and stage 1 main drilling (2.8 mm), cone beam computed tomography (CBCT) imaging of the whole sample was performed. Then the chosen implantation sites were extracted, embedded in polymethylmethacrylate and scanned using a micro-computed tomography (µCT) device. The embedded samples were then tested in an ISO 14801 configuration to obtain stiffness (ST) and ultimate force (UF) as a direct measure of the primary stability of each sample. Image analysis on the µCT scans and calculations on the mechanical data have been conducted using Python.

Fig. 1 Mandibula cut into implantation sites.

Linear regression between the bone density(BV/TV) at the implantation site, IT, ST and UF, as well as multiple linear regression models to assess anatomical factors influencing IT, ST and UF were performed using RStudio.

Results

BV/TV varied considerably among the various implantation sites (7% – 69%). Despite high heterogeneity, good linear correlations were observed between BV/TV, IT, ST and UF for both implant diameters: R = 0.79 & 0.72 for IT-BV/TV, R = 0.82 & 0.75 for UF-BV/TV and a somewhat weaker R = 0.62 & 0.60 for ST-BV/TV.

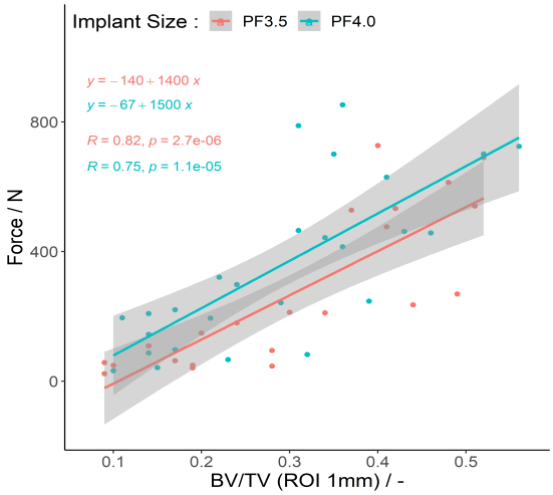

Fig. 2 Linear correlation between UF and BV/TV. Orange: sites with 3.5 mm, Teal: sites with 4.0 mm.

Discussion

The results from this study confirm BV/TV as a strong predictor of primary stability despite the large sample heterogeneity. Accordingly, quantitative CBCT may offer a non-destructive alternative to direct measurements. Additionally, multiple linear analysis showed that the implant size has a meaningful effect on primary stability as well. The data collected in this study will allow the validation of an explicit finite element method to simulate primary stability and to help optimise implant design at a given anatomical site of the human jaw.

References

Voumard B. et al, J Mech Behav Biomed Mater 92: 24-32, 2019.

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