

Abstract

This research introduces a novel helically trilobed dental implant geometry designed to enhance osseointegration through improved form closure and increased bone engagement at reduced osteotomy. By minimizing the amount of bone removed during drilling, the proposed design preserves valuable bone tissue and facilitates easier, more comfortable implant placement for the patient. Additionally, accelerated osseointegration with nano-surface supports immediate or early loading, thereby reducing overall treatment duration. The helically trilobed implant designs were developed and evaluated using static finite element analysis (FEA) under fully osseointegrated conditions to ensure safe bone–implant interfacial stress distribution. Following verification of the novel design from the state-of-the-art patented dental implant system of IIT Delhi, the implants were manufactured. Dental implants are typically machined on CNC sliding-head multi-axis machines to achieve consistent precision and high production efficiency. However, machining helically lobed geometries necessitates the use of a polygonal turning attachment on the sliding head turn mill. This work thus provides insights into achieving such geometries at reduced cycle times by leveraging the process kinematics at fractional speed ratios, offering an alternative to conventional C-axis-assisted milling. A mathematical framework for generating various lobed helical profiles is established, along with a corresponding model for predicting machining time. A MATLAB® app was developed to assist the machinist/ programmer in choosing the correct machining parameters for the desired helix angle on the part. Furthermore, the influence of machining parameters on cutting time is examined through analytical methods and experimentally verified. This analysis contributes to the understanding of production cycle time and offers a foundation for future studies on tool failure mechanisms. Using the developed helical polygon turning methodology, three helically trilobed implant variants HA, HB, and HD with helix angles 25.5° , 15.5° and 45° were successfully machined. Subsequent cleaning and surface treatment processes were performed to generate a nanoscale surface topography that enhances osseointegration and provides potential for drug-loading functionality. Mechanical testing was then performed on artificial bone (sawbones) to assess insertion torque, removal torque, and pull-out strength, each of which serves as a direct indicator of primary stability. HB design offered maximum torque reduction and uncompromised implant stability quotient (ISQ) in all the bone types demonstrating overall superiority among the considered designs. Based on these results, an

osteotomy chart was formulated to guide clinicians in selecting the optimal drilling protocol for various implant size variants. The final implants were packaged in a cleanroom environment, sterilized using gamma irradiation, and subsequently submitted to the clinical partner, MAIDS (Maulana Azad Institute for Dental Sciences), for clinical trials. This work is an offshoot of the previous works and amalgamates the new state-of-the-art work of lobular dental implants into a novel product developed and ready to be transferred to industry by IITD.

Keywords: Dental Implant, Titanium machining, Polygonal turning, Osseointegration, FE analysis, Lobular implants.