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Finite Element Analysis of Dental Implant Surgical Guides on Fluent

Varun Arora*1, Sanjeev Kumar2, Parveen Kalra3, Rahul Datta4

*1Mechanical Engineering Department, Punjab Engineering College, Chandigarh, India
2Mechanical Engineering Department, Punjab Engineering College, Chandigarh, India
3Production & Industrial Engineering Department, Punjab Engineering College, Chandigarh, India
4Datta Dental, #416, 2nd floor, Secotr-37A, Chandigarh, India

ABSTRACT

The main goal of this paper is to present the fluid flow analysis of different designs of surgical guides used for dental implant surgery. By taking into consideration the drawbacks of standard dental drill guides available in the market i.e. rise in bone temperature while drilling, a new drill guide has been designed. Fluent module of finite element methods (Ansys) is used to perform this analysis. Flow of irrigant during drilling is compared using two different drill guide designs. Results of this study show that, with the use of new design of drill guides irrigant flow is better, which will further results in better heat dissipation and lower bone temperature.

Keywords: Surgical Guides, Dental Implants, Fluent, Streamlines, Thermal Necrosis.

I. INTRODUCTION

There are multiple options for replacing the missing teeth like dentures, bridges and dental implants and the most advance among them are dental implants. Therefore, dental implants are considered most preferred treatment for the replacement of missing teeth [7]. Implants can be used to replace single teeth and they can also hold several teeth to replace a fix bridge and secure removal partial / full dentures [2].

The main reason behind the success of dental implant is the biocompatibility of Titanium, due to which it bond to bone by the process of osseointegration. Osseointegration depends upon many factors but the most crucial of these is the presence of vital bone with healthy osteoblast/ostecyte surrounding the implant. For this reason it is crucial to prevent overheating of bone during drilling process. One of the primary requirement for the placement of the implant is the cavity in which implant has to placed and it is created by drilling the jaw bone. While performing the drilling, bone temperature needs to be kept below threshold temperature of necrosis i.e. 47°C, which is done by sequential drilling and constant irrigation.

As dental implants are now recognized dental treatment, the variety of its applications to challenging situations having limited amount and quality of bone has enhanced. In these kind of situations, proper estimate of the bone quality, decisions regarding the positioning of implant, as well as accurate drilling into the bone are crucial for guaranteeing the successful placement of a dental implant. To conquer these types of complexities and successfully achieve risk-free and precise procedures, CAD / CAM guides are required. Drill guides also acts as a useful tool for inexperienced dentists and trainees [6].

Use of surgical guides for dental implant surgery can increase the bone temperature while performing surgery because of the restriction introduced by the small clearance between the drill bit and the internal diameter of the guiding cylinders / bush / sleeve. This restriction can limit the required amount of irrigant flow to the drilling site. Rise in temperature can result in thermal necrosis and trigger numerous challenges such as bone cell death, longer healing times and weak bond between the implant and the jaw bone.

In order to address the problems associated with the drill guides available in the market, an attempt has been made to design and develop a dental drill guide having improved external irrigation system as inbuilt feature to eliminate the negative aspect of existing dental drill guide.

II. DRILL GUIDE DESIGN AND FABRICATION

A dental drill guide is generally made-up of two parts: sleeves / bushes (which function as a guiding cylinder) and the contact surface or template "Fig. 1". Sleeves are usually are made of surgical grade stainless steel but templates can be made by several 3D printing techniques.

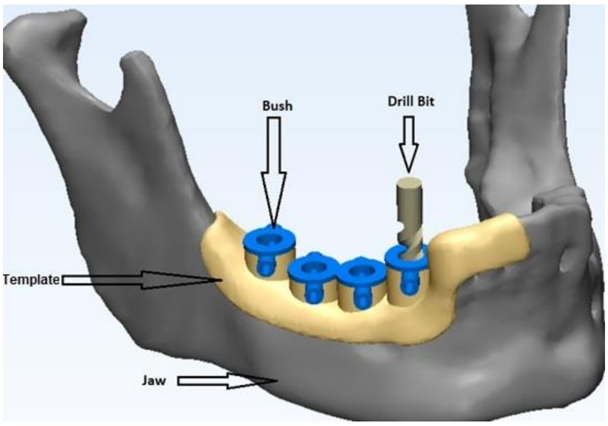

Figure 1: Schematic arrangement of 3D printed dental drill guide placed over a Mandible

Template design is four step process, which involves diagnosis, image acquisition, image processing and fabrication. After diagnosis and data acquisition by CT scanning, template is designed using image processing software MIS (Mimics Innovation Suite). The designed template is fabricated by means of FDM based 3D printing technology.

With the motive of accomplishing main goal i.e to improve the flow of irrigant at the drilling site for decreasing the bone temperature, various brainstorming sessions were planned and our team came up with an idea of providing irrigation channels in the internal diameter of bush through grooves. The supply of irrigant to these irrigation channels is via inlet tubes brazed in the transverse axis of the bush "Fig. 2". Within this new technique of irrigation, liquid supply is from two directions which maximize the liquid circulation for cooling as well as elimination of bone debris / chips.

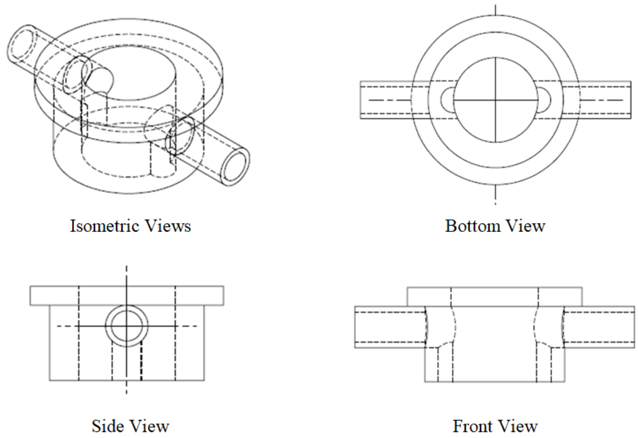

Figure 2: Different views of improved bush / sleeve, used in dental drill guide

III. MATERILAS AND METHORDS

With the intention to examine the new design in terms of supply of irrigant at the drilling site, finite elements method is used. Compression is made between the two designs using fluent module of ansys by modelling streamlines of the irrigant flow.

Streamline is the path of imaginary particles suspended in the fluid and carried along with it. In steady flow, the fluid is in motion but the streamlines are fixed. Where streamlines crowd together, the fluid speed is relatively high; where they open out, the fluid is relatively still [5].

Geometry contains assembly four parts "Fig. 3" drill, bush, body (acting as a bone) and the fluid part. All the parts except fluid part were considered solid, where as it is considered liquid because it is a space between the drill bit and the bone from which liquid has to pass. It is created by Boolean subtracting the drill bit from the fluid part.

As the shape of the bone is complicated and to simplify this, a cylindrical body of diameter 25 mm 13 mm is considered as bone as shown in "Fig. 3". The material of dill and bush is considered as Stainless steel. Water is considered as an irrigant. The initial temperature of all the elements is taken as 27°C. Mesh of the both the designs being compared is created using standard settings of the software "Fig. 4".

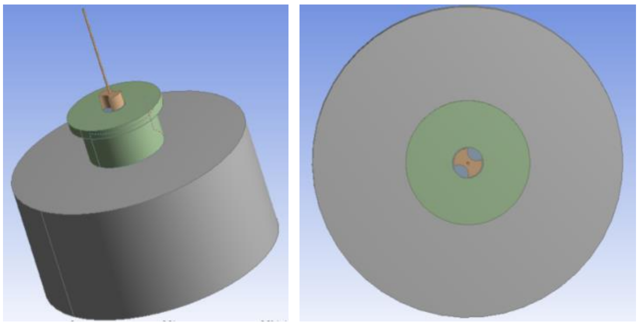

Figure 3: Graphical representation of geometry

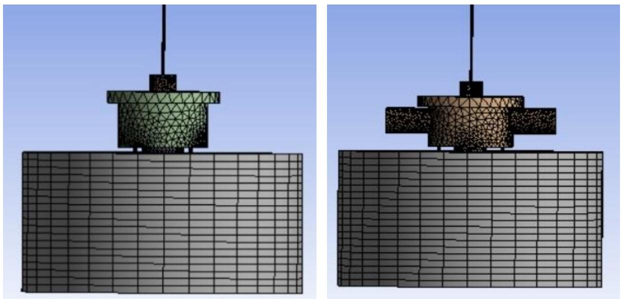

Figure 4: Assemblies of designs to be compared after meshing

In both the designs different input were assigned whereas output are considered same. Boundary conditions are assigned to fluid in which, it is given velocity magnitude (m/s) and temperature (K).

IV. RESULTS AND CONCLUSIONS

After running the calculation of both the design, their stream lines were generated in CFD post "Fig. 5".

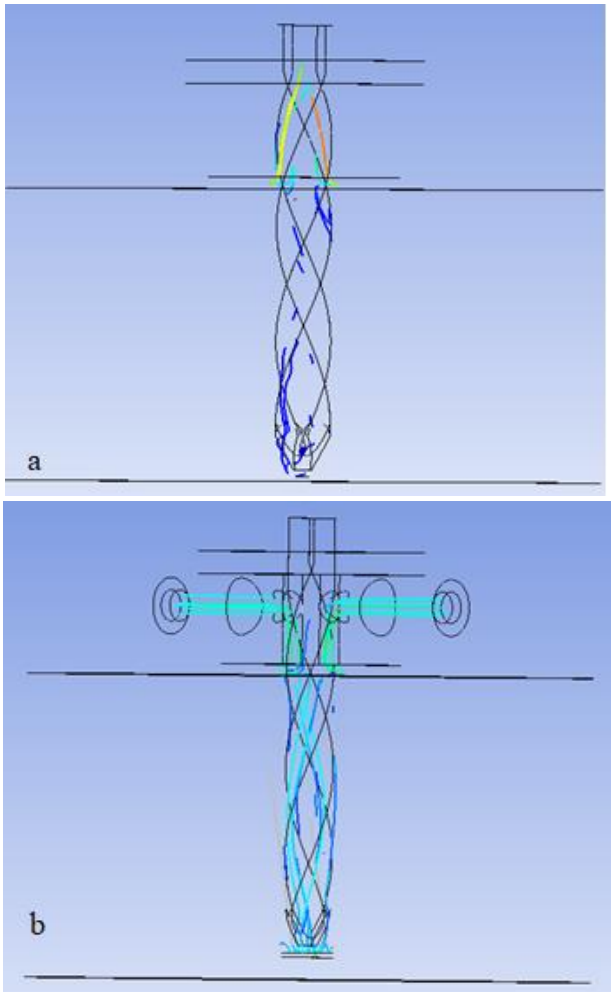

Figure 5: Streamlines of (a) conventional and (b) new design

From the analysis of streamlines, it is clear that, in the new design circulation of irrigation is better in comparison to the conventional design because of the multiple channel input. It will be also capable of bone chips in more efficient manner.

Considering a situation, where passage for the entry of irrigant (drill flutes) may get block due to the bone debris, the proposed design is also expected to perform well in this kind of situation. The design of drill guide proposed in this research has low cost, robust external irrigation delivery system in addition to standard drill guide.

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