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A review of the Application of Additive Manufacturing in Endodontic access opening using SLM process

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ABSTRACT

3D Printing refers to a class of technology that can automatically construct 3-dimensional physical models from Computer Aided Design (CAD) data. Reduction of product development cycle time is a major concern in industries for achieving competitive advantage. Endodontic dentistry is the dental specialty concerned with the study and treatment of the dental pulp, and generally diagnose tooth pain and perform root canal treatment and other procedures relating to the interior of the tooth. This article, therefore, aims on being an assistive methodology in endodontics by applying 3D printing in order to reduce the strain involved in the tooth restoration process.

Keywords : 3D Printing, Computer Aided Design, maxilla, Endodontist

I. INTRODUCTION

The human teeth function to mechanically break down large food particles by cutting and crushing them in preparation for swallowing and digesting. Humans have four types of teeth: incisors, canines, premolars, and molars, each with a specific function. The incisors cut the food, the canines tear the food and the molars and premolars crush the food. The roots of teeth are embedded in the maxilla (upper jaw) or the mandible (lower jaw) and are covered by gums. Teeth are made of multiple tissues of varying density and hardness.

Preservation of teeth by endodontic therapy has gained lot of popularity because of increased and predictable success rate of our endodontic procedures, the reason for this being the complete understanding of endodontic pathology and our ability to combat the same. Essentially, endodontic infection is the infection of the dental root canal system and the major etiologic agent of apical periodontitis

Endodontic treatment or root canal treatment is necessary when the central tissue within the tooth, known as the pulp, housing the blood vessels, nerves and living connective tissue become infected or inflamed. The root canal procedure is performed to save a damaged or badly infected tooth, instead of extracting it. This procedure is performed by a general dentist or/and a root canal specialist (Endodontist). The most common causes of tooth damage or infection are, cavities occurring due to plaque accumulation, cracked or broken tooth due to any trauma, gum diseases, and repeated dental treatment to a particular tooth. These issues can cause pulp inflammation, infection and damage the pulp irreversibly. The person will at times experience

excruciating pain. The pain may subside when the pulp dies completely, but very often returns as the infection spreads into the bone [2].

Access cavity preparation is the first clinical step in endodontic treatment and is a key step toward the healing of pulpal and periapical infection. It should allow endodontists to remove all infected tissues and obstructions in the pulp chamber, to locate all canal orifices and to clean the entire root canal system with minimum coronal tooth structure removed. Improper access preparation can lead to a multitude of subsequent treatment errors and ultimately cause failure.

The aim of this paper is to review the fabrication a guiding component for endodontic access opening using SLM 3D printing process which will provide the dentist with an efficient and accurate solution to drill to the canal orifice thereby retaining a majority of the tooth which would otherwise be lost by traditional access opening methods.

II. LITERATURE REVIEW

This section discusses the literature referred to in the form of various technical papers as well as textbooks in order to establish a base for this thesis and puts forth the summary of the information relevant front the point of view of this study. The literature referred is as follows:

Dawood et.al in [1] in his paper reviews the types of 3D printing technologies available and their various applications in dentistry and in maxillofacial surgery. The paper emphasises the application of 3D printing in the production of drill guides for dental implants, the production of physical models for prosthodontics, orthodontics and surgery, the manufacture of dental, cranio-maxillofacial and orthopaedic implants, and the fabrication of copings and frameworks for implant and dental restorations. It also puts forth advances in 3D imaging and modelling technologies such as cone beam computed tomography and intraoral scanning.

John Sami Mamoun [2] in his paper describes the basic clinical techniques for performing a maxillary molar endodontic access opening. He also explains how the use of dental surgical operating microscope coupled with head mounted illumination improves the ability of a dentist to identify microscopic root canal orifices which facilitates the efficient creating of conservative access openings with adequate straight line access in maxillary molars.

L Lakshmi Narayanan and C Vaishnavi [3] in their paper give an insight of the microbiology involved in endodontic pathology and discusses its role in the treatment procedure.

Elluru Venkatesh & Snehal Venkatesh Elluru [4] in their paper provide an overview of basics of CBCT technology and reviews the specific application of CBCT technology to oral and maxillofacial region with few illustrations. The objective of this article is to take into consideration how the introduction of cone beam computed tomography (CBCT) devices, changed the way oral and maxillofacial radiology is practiced and how it was embraced into the dental settings very rapidly due to its compact size, low cost & low ionizing radiation exposure when compared to medical computed tomography.

Jiang Hiesh [5] in his second edition of the book lays emphasis on the principles, design artifacts and recent advances in the field of computed tomography. Advancements made in many areas of clinical application including the rapid development of cardiac CT imaging have been put down thoroughly in this book.

G. R. J. Swennen et.al [6] in their paper describes the application areas of Cone Beam Computed Tomography viz. maxillofacial imaging, 3D virtual planning of orthognathic and facial orthomorphic surgery. The authors, in this paper, have conducted a

study to evaluate the use of a double CBCT scan procedure with a modified wax bite wafer in order to obtain a 3D virtual skull model with a detailed dental surface.

Francesc Abella et.al [7] in their paper manage to establish the fact that CBCT has great potential to become a valuable tool for diagnosing and managing endodontic problems, as well as for assessing root fractures, apical periodontitis, resorptions, perforations, root canal anatomy and the nature of the alveolar bone topography around teeth.
William C. Scarfe et.al [8] in their review paper discuss how the small field of view images at low dose with sufficient spatial resolution provided by a CBCT can be applied in endodontic diagnosis, treatment guidance, and posttreatment evaluation. This article provides a literature review and pictorial demonstration of CBCT as an imaging adjunct for endodontics.

F. Rengier et.al [9] in their review article summarize and evaluate the generation of graspable three-dimensional objects applied for surgical planning, prosthetics and related applications using 3Dprinting or rapid prototyping.

Helena N Chia et.al [10] in their paper focus on the recent advances in the additive manufacturing industry in the field of bio-compatible materials. This paper explain in detail the need as well as the importance of using bio-compatible materials for 3D printing of complex organs and bodily structures.

Dax Abraham et.al [11] in their case report emphasize on the importance of Cone Beam Computed Tomography prior to initializing a root canal treatment how important it is for the clinical dentists should be aware of the anatomical variations in maxillary molars.

C. K. Chua et.al [12] in their review paper explain the process of selective laser melting and give a brief background of how the process was developed and realized. They also lay great emphasis on the development of materials to further enable the process to improve. They have given detailed information about the scope and the applications of SLM process.

Siavash H. Khajavi et.al [13] in their paper analyse the impact of cheaper metal powder supplies on the comparative competitiveness of additive manufacturing. By utilising two case studies, they compare the economic impact of an innovative titanium extraction method on Selective Laser Melting (SLM) and conventional methods of machining and casting.

P.J. Kale et.al [14] in their paper present Rapid Prototyping as a best tool for dental prosthesis and crown manufacturing. It also represents the static structural analysis of dental crown with FEM software, ANSYS 14.5. The paper emphasises that tooth preparation is the main parameter which affects the strength of crown 3D printing is the most promising tool for Dental Prosthesis manufacturing

Guanyang Liu et.al [15] in their paper simulate an analytical force model to compute the force between a tooth and a dental pin during tooth preparation. In addition, they have also considered the effects of dental-pin type, tooth stiffness, and contact geometry in the force model. They have implemented the force model in the prototype of a dental training system that uses the Phantom as the haptic interface.

III.RESULTS AND DISCUSSION

The expected result of this thesis is that the root canal specialist (Endodontist) can utilize the technological advances of 3D printing and 3D imaging in order to obtain a guide to carry out the endodontic restoration process with greater accuracy as he is already aware of the depth to which he has to drill and in which specific location.

The various results which can be formed from the review of this article are as follows:

Time: The access opening procedure is the first step of the root canal treatment. The average approximate time range involved in drilling using the guide will be lower than by traditional method of access opening.

Tooth structure: The main aim for the use of the surgical stent is to enable the easy location of canals and restore a major proportion of the tooth structure. As there is no direct way of determining the amount of tooth structure retained apart from weighing the teeth after extraction, an approximate estimate of tooth structure retained could be determined by measuring the amount of filler composite used to fill the tooth post cleaning of the canals. However, this is not the most accurate way of determining tooth structure since the size of the tooth may vary from person to person.

Cost of production: Cost is a major factor when it comes to mass utilization in the dental industry. The stent developed for the purpose of this thesis estimated to a total developmental cost of Rs.600/- inclusive of taxes for printing it in Cobalt Chrome. Cobalt Chrome is a FDA approved material and also requires the use of a metal 3D printer which adds to the cost of the final part. As the stent is a temporary device used to guide the drill it can be made of alternative materials which are safe to use in the human mouth.

IV.CONCLUSION

From the proposed methodology the average time required for the access opening procedure was found to be lesser than the traditional method.

As a high proportion of tooth structure can be retained using the proposed approach, the requirement of a crown, post treatment, for the tooth which has undergone RCT, may be unessential in some cases thereby reducing patient expenditure on dental crowns.

The cost incurred in the fabrication of the surgical guide using SLM Metal 3D printing process costed Rs.600. This cost does not involve the cost of CBCT scanning.

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