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A Real-Time Dental Implant Tracking System: A Review

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Abstract-Dental implant is one of the most popular methods of tooth root replacement used in prosthetic surgery. This paper presents a construction of a Real-time dental implant tracking system for dental implant surgery. The placement of dental implant is critical since positioning mistakes can lead to permanent damage in the nerves, numbness and failure of the implant and crown. The main goal of this study is how to measure the position, length, depth or angulations and estimation of thickness of jaw bone. A non-invasive system has been design using 3D electromagnetic motion tracking system for visualization of drill movement for dental treatment. Their systems either require a special tool tip calibration device or are unable to change the different tool.

Keywords-Tool tip calibration, electromagnetic tracking system, electromagnetic sensor, surgical navigation system.

1. INTRODUCTION

Dental implant is a surgical treatment of tooth root replacement which is the most frequently used in prosthetic dentistry. It can be replace missing teeth by screwing a very simple metal of medical guide such as titanium or titanium alloy into the jaw bone. The root is the part of tooth that is effectively replaced by an implant. Computerize navigation system is offered to minimize potential risk of damage to critical anatomic structures of patients. The methodology based on CIS interventions includes preoperative and intraoperative procedures. The preoperative surgery is to use 3D views as provided to enhance raw images obtained from the patient before operation. This helps to get familiar with the anatomy of the patient. The techniques are to render a target region and a pathway associated with relative organs from CT data. While intraoperative support can be used during the real surgical procedure both a navigation and a decision aid [1, 2].

A present mechanical guided system or template drill guided system is an old-fashion technology for dental implant guidance. It is derived by waxing up patient's teeth impression, and then it has to transfer the interactive planning of implants from 2D and 3D visualization to the template reality [3]. The drawbacks of this method are on the lack of interactive control during implant is operated, as well as, the high cost of drilled guided template intervention [4, 5]. Different techniques are available today for manufacturing and assembling these biomechanical systems, typically based on bridge structure, supported by a series of titanium screws implanted into the edentulous patient's jaw (Fig.1a).

Many dental techniques describe the use of different polymer printing material to measure and transfer the tridimensional information (position and orientation) of the patient's implants [6].

Despite the development of novel and more precise fabrication methods, obtaining an absolute fit is practically impossible, especially in complete and partially edentulous patients (Fig. 1b). In general, the microgap (vertical, horizontal or angular see Fig. 1c) misfit between implant components has been associated with several complications from both mechanical and biological origins. Furthermore, even through singular implant misfit are often imperceptible, the combination of several misfits in different implants may raise complications and compromise the entire prosthesis viability [7].

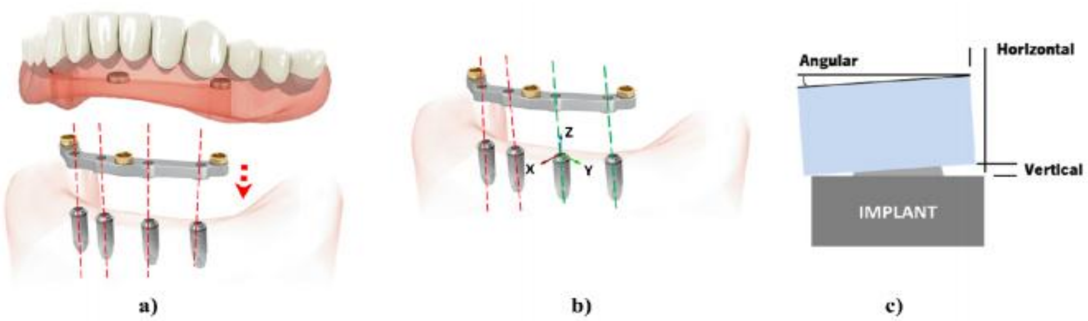

Fig.1.1 Osseointegrated Implants and Support Dental Prosthesis A) Implant without Misfit B) Implants with Partial Misfit (In Green) C) Different Types of Micro gap Misfit (Angular, Horizontal and Vertical)

2. WORKING PRINCIPLE

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A proper surgical device for real-time dental implant procedure should be as compact as possible, intuitive, and easy to setup in current operation theater domains as well as having the ability of fulfilling all the requirements in terms of tool motion and precision. To achieve these factors, a precise analysis of surgeon's motions during the operation. The main goal of this study is how to measure the tool motions position and orientation. Two methods for hand or tool motion tracking are Optical Tracking (OT) and Electromagnetic Tracking (EMT). In OT a rigid optical marker attached to the tool or on the surgeon's glove and precise position and orientation of the marker are observed by multiple cameras. In EMT, an electromagnetic field generator is used near the surgical site and the relative position and orientation of a sensor, which is attached to the tool or glove, are observed with respect to the original frame [8].

2.1 Field Generators

To create the magnetic fields needed for EM tracking, field generators are used. A field generator needs to sequentially generate at least three different magnetic fields of known geometry. Inside the FG inductors are used, these inductors are aligned in a tetrahedron shape to generate magnetic fields. An important property of each field generator is the tracking volume, which describes the area around the generator where sensor can be tracked [9].

2.2 EM Sensor

A basic component of Real-time tracking system is the magnetic sensor. Since the magnetic flux density cannot be determined directly, magnetic sensors measure the magnetic flux ϕ which is defined as the component of B that passes through a specific point/surface. A sensor only measures the gradient of a magnetic field that represents the difference in the magnetic field intensity between different positions inside the field [10].

Fig. 2.1 Electromagnetic Sensor Mounted on Surgical Tool

2.3 DAQ

With the aim of getting more realistic data, the surgeon was asked to perform the operation three times and the raw data for all motions were captured. Then the raw data was analyzed in terms of total working volume, positions, velocities, accelerations and trajectories.

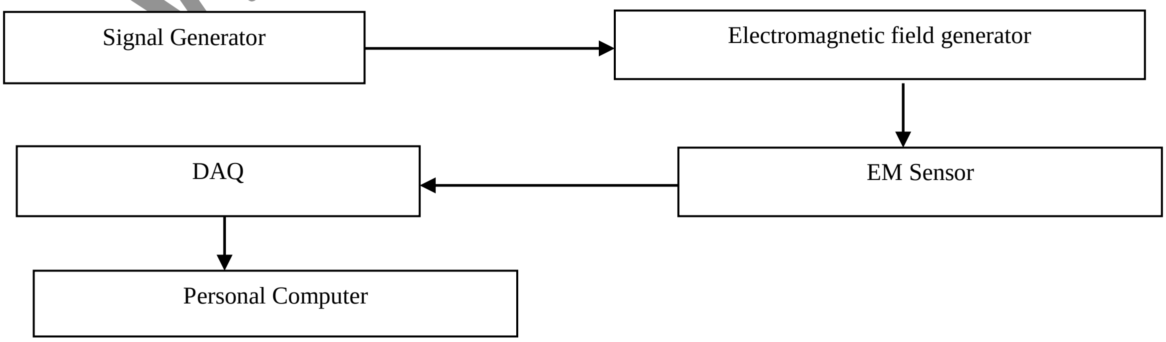

Fig. 2.2 Block Diagram of Dental Implant tracking system

3. TRACKING SYSTEMS AND TECHNOLOGIES

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In the past 30 years, a variety of tracking technologies, such as optical tracking, and electromagnetic tracking have been developed for motion capture/tracking in a wide range of fields including entertainment, sports and medical applications [11]. A tracking system is generally characterized by sample rates for data acquisition, precision, working range and degree-of-freedom (DOF).

Table-3.1 Comparison of Different Electromagnetic Tracking Systems

Two techniques for hand or tool motion tracking are Optical Tracking (OT) and Electromagnetic Tracking

System	Radial Distance from field Generator	Position Accuracy		Orientation Accuracy		Update Rate
		RMS	95%	RMS	95%	
Ascension microBIRD	305mm	1.4 Mm	–	0.5^0	–	90 Hz
Polhemus FASTRAK	–	0.71 Mm	–	0.15^0	–	120 Hz
NDI Aurora	250mm 450mm	0.9 mm 1.6 mm	2.0mm 3.0mm	0.8^0 1.1^0	1.5^0 1.7^0	40 Hz

(EMT). Optical tracking systems (OTS) consist of a receiver unit including two or more cameras and a set of special markers attached to the object. The 3D position of the markers can be calculated by using geometry and image processing on the images acquired from the stereoscopic cameras.

EMTS consists of three components: field generator (FG), sensor unit and central control unit. The FG uses several coils to generate a position varying magnetic field that is used to establish the coordinate space. The sensor unit attached to the object contains small coils in which current is induced via the magnetic field. By measuring the behavior of each coil, the position and orientation of the object can be determined. Although the precision of OT is better than EMT, a continuous visibility of the markers needs to be maintained during the procedure, i.e. occlusion must be avoided. Furthermore, the marker is not small as small as EMT sensors, so the weight and length added to the tool are not negligible. Consequently, the motions during procedure which have limited movements with limited forces, such as in dental implant surgery, completely change in the presence of current OT markers. Thus, a promising alternative method for dental implant surgical tool tracking is EMT, where the visibility of the sensors is not a factor, and the sensor weight and size are negligible. In this work an electromagnetic tracking system used to observe surgeon's tool motions during a real time dental treatment. Since the complete tracking data with relevant analysis during surgery has not been collected before, this data can be used to optimize the design of a medical assisted device for surgery and simplify the tradeoff between compactness and performance for engineers.

4. ADVANTAGES OF TRACKING SYSTEMS

The main advantage of OTS is the highest accuracy provided by optical trackers. Optical tracker does not suffer from measurement distortion due to ferromagnetic as electromagnetic techniques do, or from drift problem like inertial sensors. The main drawbacks of optical tracking system are high cost and require maintaining a line of sight as compare to EMT system. OTS cannot track instrument inside the body as compare to EMT system.

5. COMPARISON OF DIFFERENT ELECTROMAGNETIC TRACKING SYSTEMS

Electromagnetic tracking is capable of very high accuracy and low latency, EM technology has become the gold standard noncontact tracking solution, where accessibility or line-of-sight restrictions could cause competing technologies to fail. One of the biggest drawbacks with electromagnetic tracking is that the operating Environment must be free from magnetic and ferromagnetic material. Anything that generates or perturbs magnetic fields will degrade system performance..

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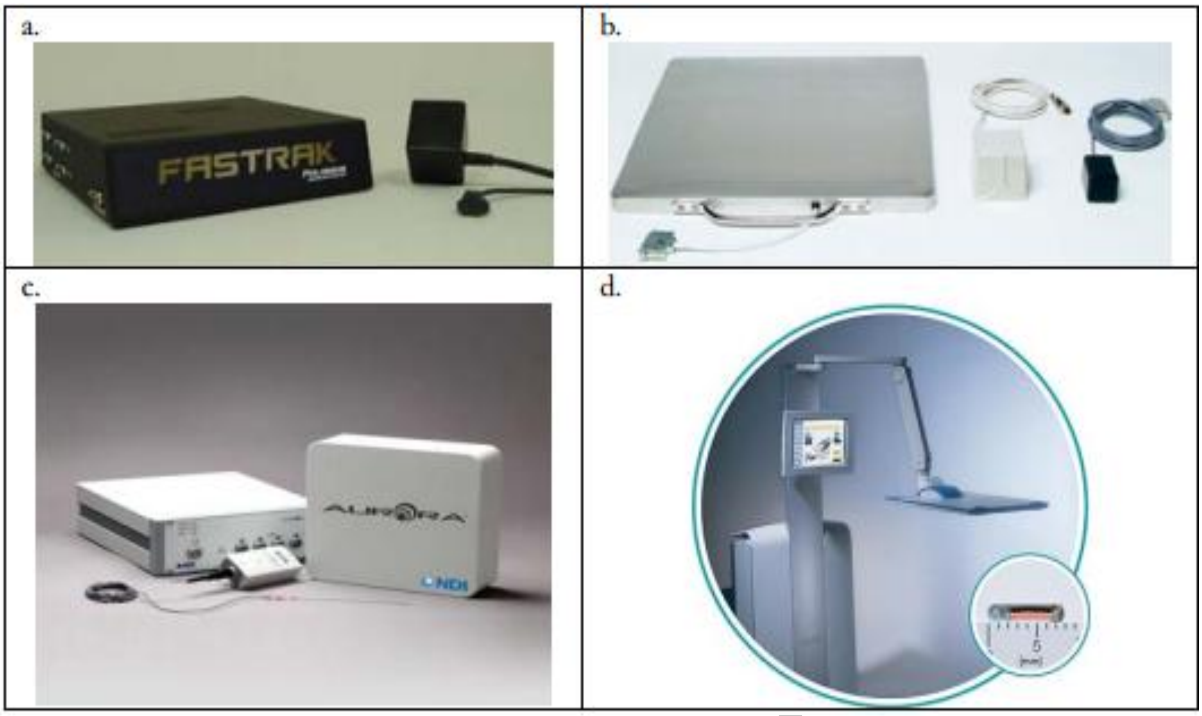

Fig. 5.1 Electromagnetic Tracking Systems for Medical Applications: (a) Polhemus Fastrak (b) Ascension microBIRD (c) NDI Aurora (d) Calypso

Additionally, electromagnetic trackers have a limited operating volume with accuracy and precision degrading as the radial distance from the field generator increases. Finally, EM tracking solutions are expensive, often costing tens of thousands of dollars.

The first three are wired tracking systems while the Calypso tracking system is the only tracking device which utilizes wireless tracking.

CONCLUSION

In this study the surgical motion during dental implant surgery was clinical captured and analyzed. For this purpose an experimental set up with a combination of electromagnetic tracking system and an electromagnetic sensor was developed. Electromagnetic tracking system is inexpensive as compare to optical tracking system. The expected outcome of this study is as follows: The Experimental data contain trajectory and working volume of the tool, position analysis, and orientation analysis of tool during the procedures and emergency reaction by the surgeon.

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