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RESEARCH ARTICLE

APPLICATION OF DIGITAL TECHNOLOGY IN IMPLANT DENTISTRY-AN OVERVIEW

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Abstract

Implants are considered as potential alternatives while replacing missing teeth. Accurate planning and placement of implants in a predetermined position, plays an important role in determining the success of the prosthesis. Digital technology refers to the usage of computer controlled components that minimize manual work. In the past decade, digital technologies, like cone beam computer tomography, have been used right from diagnostic phase to treatment planning phase. With the advent of augmented reality, digital technology can be used even during the surgical phase.

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Introduction:-

Digitalisation has imprinted its unique identity in every field and dentistry is not an exception to it. Implant dentistry is one clinical area where digital technology can be used to its fullest extent[11].Digital technology is used right from patient examination to prosthesis fabrication. Final prosthetic outcome can be visualised and explained to the patient even before surgical placement of implants[3]. These Novel technologies not only reduce the time consumption but also improve the quality of care given to the patients. The following article will have an over view about the digital work flow while planning and placing the implants and during the prosthetic phase.

Application Of Digital Technology In The Surgical Phase

Cone beam computed tomography: In contrast to computed tomography, CBCT uses a "cone"shaped source of ionizing radiation to acquire multiple sequential projection images (2D) in one complex scan around the area of interest. Once the two dimensional images are acquired, the native software does the image reconstruction process and a 3D volumetric data is obtained[9]. Subsequently, orthogonal (sagittal, coronal and axial) sectioning can be done and the anatomic structures are visualised. Some anatomic structures which cannot be visualised in orthogonal sections can be viewed in non orthogonal planes with the help of multiplanar reformatting process[9]. The image obtained can be exported in DICOM format for further processing[21].

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Possible applications of CBCT

1. During the diagnostic phase it is useful in evaluating the 3D edentulous areas in relation to bone quantity and relative quality.
2. During Implant planning phase, it helps to assess the proximity of vital structures like inferior alveolar canal, mental foramen, maxillary sinus, adjacent tooth root and inherent concavities of the bone can be accurately measured[4].
3. CBCT DICOM data are exported to software and converted into STL files and used in fabrication of surgical template /stent[8].
4. Post operative assessment of osseointegration and grafting procedures can be done.

Static Navigation

The term 'static' is used because the implants are placed without real time visualisation as they are placed in the surgical site[6]. This is also referred to as semi-active CBCT-aided implant surgery[4]. By merging virtually planned prosthesis design and digital information obtained from CBCT, it is possible to fabricate a guiding stent by rapid prototyping, rapid printing or using stereolithography. These stents help in precise placement of implants in relation to depth, position and angulations[14]. These guiding stents can be soft tissue supported, tooth supported, bone supported or combination of the above[24].

Dual scan technique[8]:

If the patients existing dentures are found to be satisfactory in esthetics and function, then it can be converted into a radiographic template by placing fiducial markers on the duplicate dentures (figure 1). Sometimes a laboratory fabricated radiographic template is also used (figure-2). First data set is obtained by CBCT imaging of the patient with the radiographic template/duplicate dentures with radiopaque markers in mouth.

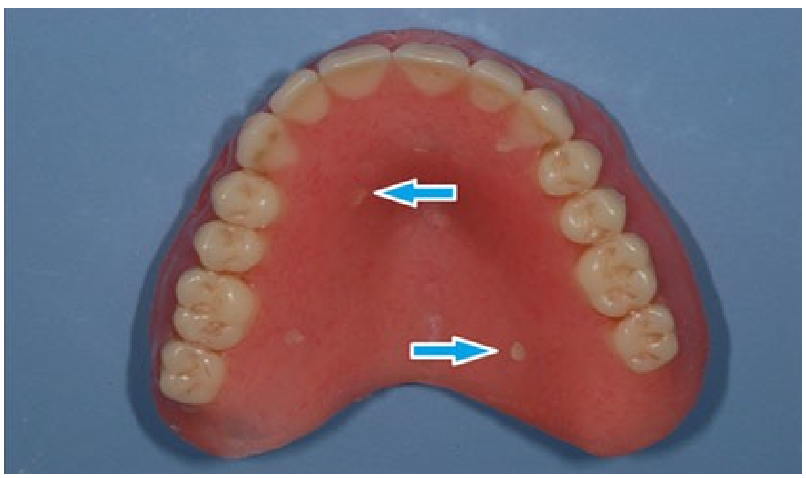

Figure-1:- Duplicate dentures with radiopaque markers.

Figure-2:- Radiographic template with radiopaque teeth.

The second set data is obtained by CBCT imaging the radiographic template alone. The radiographic template which is devoid of any metallic restoration, and implants will prevent the development of artefact (figure-3). Thus the clean occlusal surface obtained from the radiographic template can be merged to the first data set with the help of fiducial markers and sent to the laboratory for the fabrication of surgical stent.

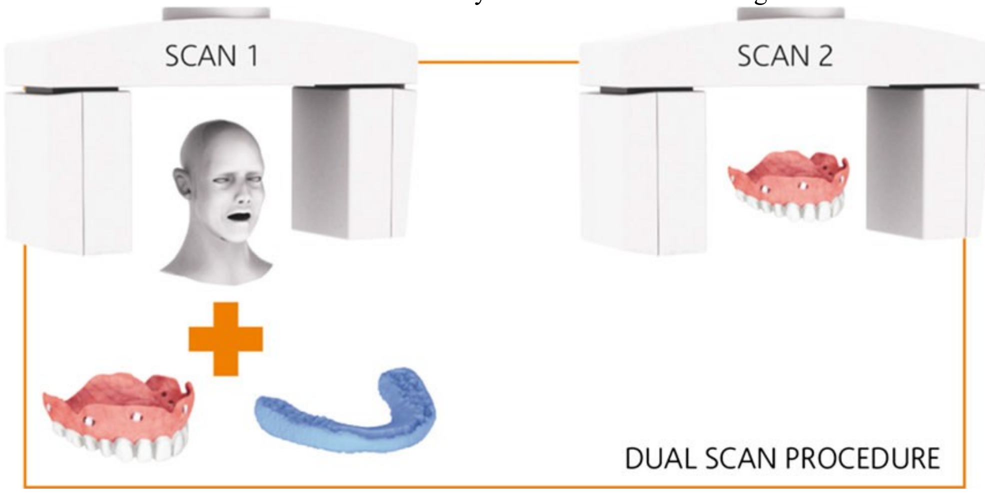

Figure-3:- picture depicting dual scan protocol.

Using the data from dual scan procedure, surgical stents are fabricated with the help of stereolithography (figure-4). Some drill guidance allow only for the usage of pilot drill. Multiple surgical guides with varying diameter of drill guides can also be fabricated to precisely place the implants. In, sleeve-in-sleeve concept, a single surgical guide with multiple sleeves with varying diameter is also fabricated[17].

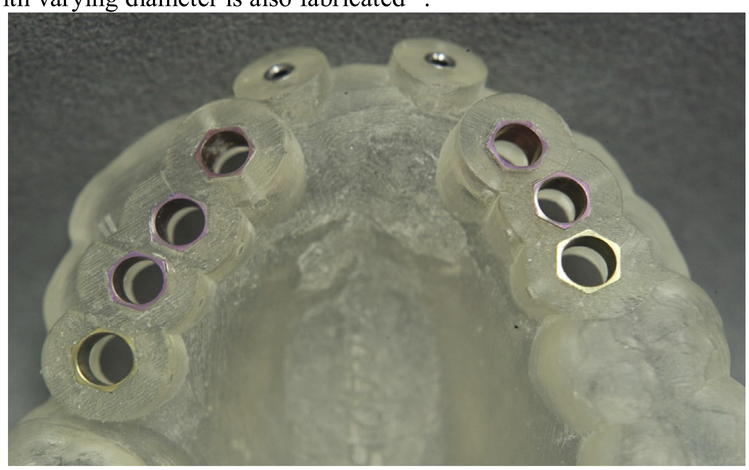

Figure-4:- surgical stent fabricated using stereolithography.

The advantage of static navigation is that it prevents manual errors associated with freehand surgeries by precisely guiding the osteotomy drills, the surgical procedure is minimally invasive and provisional restorations can be fabricated even before surgical placement of implants and can be given to the patients as immediate provisionalization[14].

The disadvantage is that neither the surgical site can be visualised nor the angulation can be changed while placing implants, unless the surgical stent is abandoned[6]. Amount of interocclusal space becomes a critical factor that has to be considered while planning a guided surgery. To overcome this problem some companies provide drill guides with lateral tube openings [24].

Dynamic Navigation:

Dynamic navigation is based on optical technology that uses tracking arrays which are positioned on the patient's jaw and hand piece. Implants can be placed using real time visualisation of the surgical site.

The work flow for dynamic navigation is as follows[12].

STENT:
A thermoplastic retainer is moulded and placed on the same arch where the implants are to be placed, but on the opposite side, without hindering the implant position. To this retainer, an arm is made of the same thermoplastic material and fiducial markers are attached.

SCAN:
With the retainer and retainer arm secured in the oral cavity, a CBCT scanning is done

PLAN:
A DICOM file generated during CBCT scanning is transferred to the navigation software.STL files of the virtual wax up or the natural dentition obtained during intraoral scanning procedures is also imported to the navigation software. Using DICOM and STL files virtual planning of the implant position is done

PLACE:
Once the final position of the implant is planned using software, the fiducial markers present in the retainer are replaced with optical markers. Another optical marker is placed on the handpiece. The optical markers placed in the hand piece and patient's oral cavity (retainers with optical markers) helps in triangulation, thus helps in accurate navigation[8]. The light source, which is placed above the patient, reaches the optical markers (optical arrays) and it is reflected back to the stereo cameras placed near the light source. The reflected light is processed by the software to provide real time imaging of the surgical site on the computer monitor (FIGURE-5). A 'bulls eye' target view or 'hair line' view on the monitor gives information regarding the proximity of the drill guide to the planned implant position in relation to the angle of the drill guide to the central axis, distance between the drill guide and the central axis in millimetre and distance between the tip of the drill guide to the apical end of the planned osteotomy. Once the osteotomy site is prepared the implants are placed to its final depth in 'fully guided navigation'. In case of 'partially guided navigation' at least 50% implant placement is placed by hand until its final depth is reached[8].

Figure-5:- Retainers with Optical markers are placed on the right side of the mandibular arch. Another optical marker is place on the hand piece. Blue lines represent the emitted light. Green arrow represents the reflected light that is captured by the cameras.

The primary advantage of dynamic navigation system is that the accuracy of implant placement[6]. It is possible to change the implant size, position and implant system intra-operatively, which is not possible with static navigation system. But the disadvantage is that a long learning curve is required by the surgeon.

Application Of Digital Technology In The Prosthetic Phase
Extra oral scanners:
Using CAD-CAM technology, the prosthesis can be fabricated digitally using a conventional silicone impression. This procedure is referred as in- direct workflow, where a dental stone cast which is made from a silicone impression is scanned using laboratory extra oral scanners[15]. Though the extra oral scanning is adequate to fabricate prosthesis, finer intra oral details are missed due to changes in impression material and the stone cast[23]. Procera Scanner from Nobel Biocare is an example of extra oral scanner[5].

Intra oral scanners (IOS):
Manual errors in making the impression, volumetric changes with impression material and problems in storing the model led to the widespread usage of IOS in dentistry, which overcame the problems associated with the conventional impression making. Thus the process of IOS is also referred to as digital impression making[2]. The intra oral scanners are of two types a) contact type b) non contact type. Non contact types of scanners are most commonly used.

The digital work flow for a prosthesis fabrication begins with data acquisition, designing the prosthesis virtually and manufacturing of the prosthesis. Data acquisition is done using intraoral scanners (IOS). It is composed of a handheld camera, a computer, and software[20]. It acquires the 3 dimensional positions of teeth (and/or implant) and related structures. The acquired position of an object is processed by the software and point clouds are generated[13]. When the point clouds are denser; the virtual reconstruction of the object, being scanned, will also be accurate[15]. These point clouds are processed by the software to produce the virtual image of an object.

Implant scan bodies (ISB) are usually used in conjunction with the intraoral scanners. They represent the digital version of the impression coping[11]. These implant position transferring devices exactly transfer the 3 dimensional position of the implant for the fabrication of a restoration[15]. Once the position of ISB is optically scanned, digital implant analogue is virtually placed in the model from the ISB/ implant library. There are various types of scan body available, based on shape, size, reusability, compatibility with the IOS software

There are basically three types of intra oral scanners[2]:
a- Powder painting scanner,
b- Active wave-front sampling scanner and,
c- Parallel confocal laser scanner.

The advantages of intraoral scanners are that, it is time efficient, can be used in patients with severe gag reflex[13]. Communication with the patient and the dental technician is very much improved. The need for large storage space for dental models is also eliminated. However the disadvantage is that a long learning curve is required and the finish lines cannot be registered with accuracy.

CAD/CAM:
Francois Duret introduced CAD/CAM in restorative dentistry in the year 1971 [7] and CAD/CAM fabricated crown was first delivered to the patient in the year 1985[19]. Since then it has been widely used in the fabrication of fixed dental prosthesis, inlays, onlays and veneers. In the field of implant dentistry it is widely used in the fabrication of implants, custom abutments, framework fabrication and prosthesis fabrication. The steps like wax pattern fabrication, investing and casting are eliminated, and thus the fit of the final prosthesis is very accurate.

CAD/CAM systems contain 3 important components[23]
1. a data acquisition unit
2. software for designing the prosthesis
3. milling unit

These CAD/CAM systems can be either open/closed type depending on the data sharing capability. Open type's CAD/CAM system allows for inter-changing ability of the data from one manufacturer to the other, in terms of data

acquisition, designing or milling. Whereas closed type prevent data sharing, thus one type of brand should be used for all phase of CAD /CAM procedure. Most of the CAD/CAM systems available are closed system[5].
Depending on the location of CAD /CAM unit, it can be divided into[5]

1) Chair side production eg) Cerec® System (Sirona)
2) Laboratory production
3) Centralised fabrication in a production centre.

CAD phase include data acquisition and virtual designing of the prosthesis with the help of software. Preliminary data of the intra oral structures can be acquired with the help of intra oral scanners or extra oral scanners. Utilising these data, prosthesis is designed virtually with the aid of the designing software. The constructed data in regards to the prosthesis is stored in STL (Standard Triangulation Language) format and exported to the milling unit. The final product is fabricated either using a subtractive milling process or additive milling process.

The advantages of using a CAD/CAM fabricated abutment is that, patient specific abutments can be manufactured with great precision and also enhances the emergence profile of the soft tissues[18](figure-6). With the aid of custom abutments milled using CAD/CAM, it is possible to alter the finish line location, thickness and external contour of the abutment[1]. The cost of CAD/CAM abutment is in between the prefabricated (stock) abutments and castable abutments.

Recent advance in the CAD/CAM abutment is the Encode Abutment (Encode; Biomet 3i, Palm Beach Gardens, Fla[1]). They dictate the position, angulation and depth of implants, hex connection and also the location of the soft tissues based on the codes encrypted on them (figure-6). After placing the implant fixture, impression transfer copings are placed and a putty index is made to register the position of the implant. This putty index will be used at a later date to fabricate the prosthesis. Once the putty material polymerizes, it is removed and encoded healing abutments are placed immediately after implant placement (figure-7). After sufficient healing has taken place (figure-8), a polyvinyl siloxane impression is made (figure-9) and a stone cast is poured (figure-10). An optical scanner reads the code present on the healing abutment and sends information to the designing software, where the encoded final abutments are virtually designed using software and fabricated using titanium alloy/zirconium(figure-11&12). Once the final encoded abutments are milled (figure-13), it is sent to the local laboratory where the prosthesis is fabricated using the cast obtained from the positioning index. The advantage is that it is possible to fabricate a prosthesis using an abutment level impression without the need for implant level impression.

Figure-6:- picture of an encode abutment

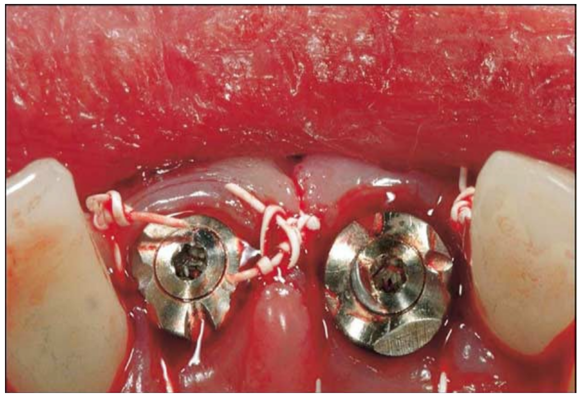

Figure-7:- Encoded healing abutment placed intraorally immediately after placing the implants.

Figure-8:- Encoded healing abutment after healing.

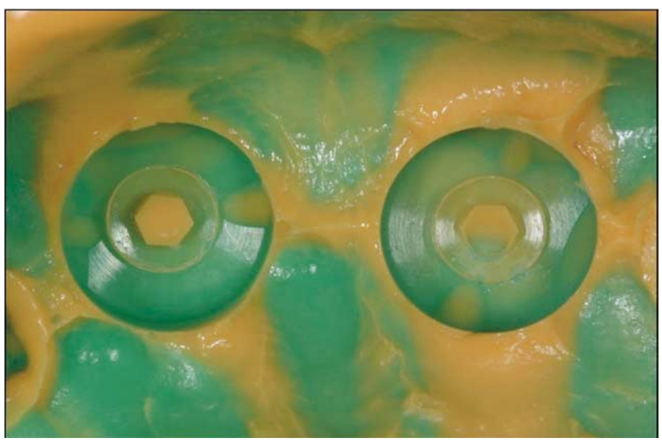

Figure-9:- PVS impression of the encoded healing abutment.

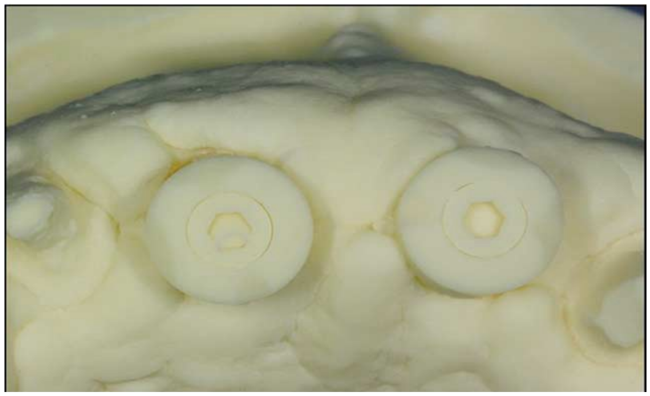

Figure-10:- stone cast.

Figure-11:- scanning of the coded healing abutment reveals the position of the implant, soft tissue and adjacent teeth.

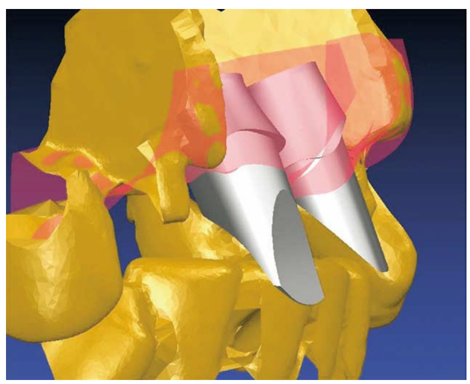

Figure-12:- Abutments are designed virtually.

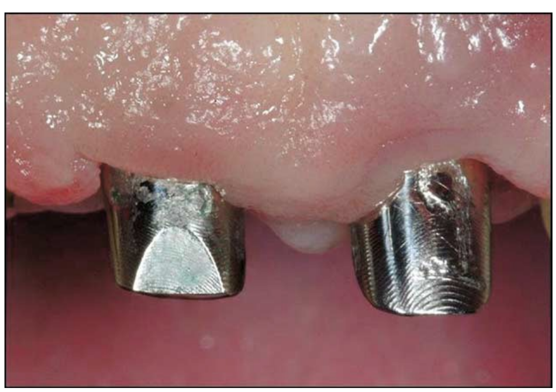

Figure-13:- final encoded Abutments are placed intra orally.

Robotics in implant dentistry:
Robots reduce the human effort in carrying out complex tasks, with utmost precision, thus it is being applied in all the fields. With the aid of robotic technology and artificial intelligence, medical robots are used to perform complex surgeries[10].

In the field of implant dentistry, the application of robots is still in its infancy stage. They are used to arrange artificial teeth and bend orthodontic wire[22]. It is also used to fabricate surgical guide with 0.15 degree of rotational accuracy and 0.04 mm of translational accuracy[10].

The ultimate aim of using robots in the field of implant dentistry is to use them during surgical procedures apart from pre-surgical planning process. Many prototypes have been developed in many parts of the world. The general components include data acquisition tool, drilling tools, strain gauge to evaluate the stress/strain relation and a sensor to monitor the torque[22]. With the help of software the robots are programmed to acquire the date intra-operatively and post operatively, plan and execute the drilling process, load the implant and simulate masticatory movements.

The first commercially available robots- guided systems were developed by Neocis Inc, USA and named it as YOMI (Figure-14).FDA approved these robots in the year 2017. It is based on navigation system, which provides assistance during pre-operative phase and intra-operative phase of implant surgery. YOMI provides physical guidance by using haptic robotic technology, which controls the drill in position, orientation and depth.

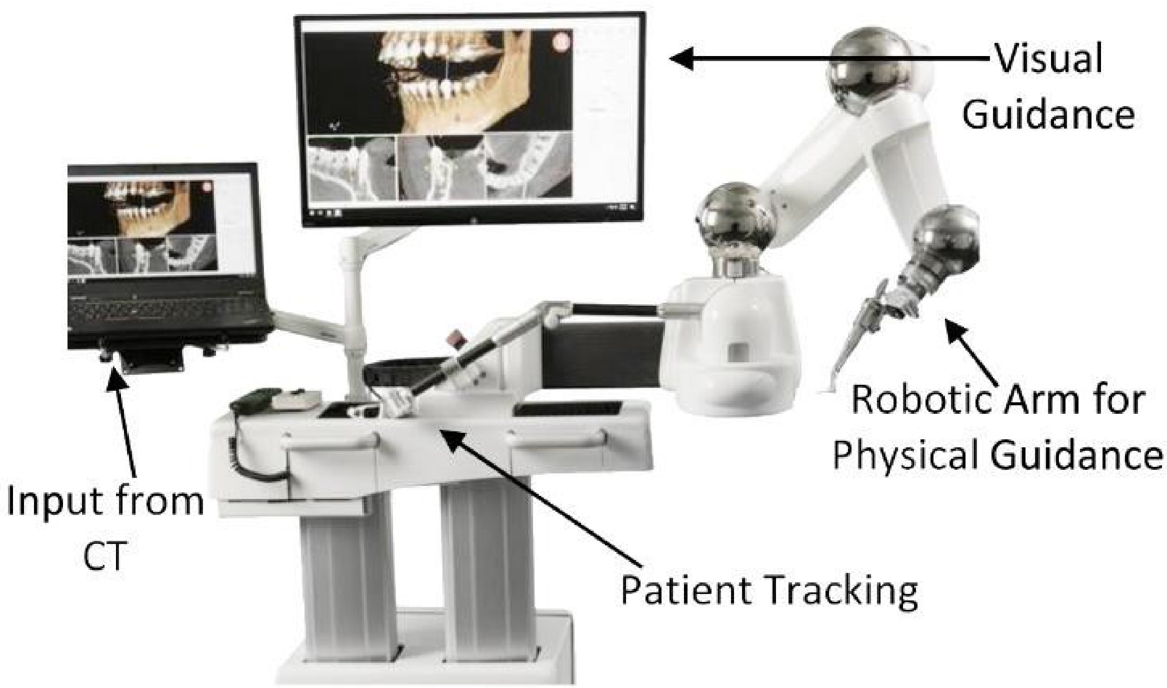

Figure-14:- YOMI robot guided dental implantology system.

Pre-operative data acquired during CT imaging is accurately transferred and implemented during the surgical phase using this virtual reality system. They provide visual and physical guidance, throughout the surgical procedure. The advantage of using YOMI is that it can be used repeatedly because of its untiring nature, unlike human beings. The ability to process the quantitative data, precision and accuracy with which the implants are placed are far better than the free handed surgeries[25]. The disadvantage is that, it cannot judge the qualitative data hence an experienced surgeon should continuously monitor the surgical procedures. These devices are very expensive[25].

According to South China Morning Post, a fully automated robot placed two implants in a female without any human touch (figure-15). This fully autonomous surgery required expert planning and supervision. Their function is similar to robot guided surgery, but with zero human intervention[16].

Figure-15:- Robot Dentist fits teeth into a woman's mouth.

Conclusion:-

The digital technology has revolutionised the field of implant dentistry and seen an exponential growth in the last decade. Laboratory tools associated with waxing, investing and casting are being replaced by the keyboard of the computer. Simplicity, accuracy and precision outweigh the cost factor in procuring the digital equipments. Despite its advantages, the success does not entirely depend on the technology, the clinicians' skill in obtaining and processing the data plays a vital role.

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