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Review Article

Contemporary Trends in Implant Dentistry – A Review

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Introduction

The study of implantology is exceptionally unique. Ever since its introduction into the field of dentistry by Dr P-I Branemark, it has experienced various changes and enhancements. New advancements of dental implants have, by and large, been centred around changes in the equipment of the implant, that is new materials, designs or surfaces have been introduced with concurrent cases of these been better than those utilised before. A portion of the latest implants use a titanium alloy substructure covered with a thin layer of either hydroxyapatite, calcium phosphate ceramic or plasma spray technique. Hydroxyapatite or tricalcium phosphate coatings are intended to deliver a bioactive surface advancing development and instigating an immediate bone between the hard tissues and the implant **[**1**]**. Advances, for example, three-dimensional dental radiography with cone-beam computed tomography (CBCT), precision dental implant planning software and clinical execution with guided surgery all play a role in the accomplishment of implant dentistry.

Advances in diagnostic imaging modalities

Imaging plays a vital part in dental implant procedures. The imaging modalities differ from standard projections routinely available in the dental office to more multifaceted radiographic techniques typically available only in radiology centres. Implant imaging delivers precise and dependable diagnostic info of the patient's structure at the planned implant site. Standard projections involve extra-oral (panoramic, lateral cephalometric) and intra-oral (periapical, occlusal) radiographs. Additional complex imaging techniques involve conventional X-rays, computed tomography (CT), and cone beam computed tomography (CBCT)**[**2**]**.

Zonography

A modification of the panoramic radiographic machine for making cross-sectional images of the jaws. The tomographic layer is ~5 mm. For an appreciation of the spatial relationship between the critical structures and the implant site.

Tomographic layers relatively thick, adjacent structures blurring, and superimposition, not useful for determining the differences in bone density or for identifying disease at an implant site.

Tomography

Tomography is the generic name formed by the Greek words 'tomo' (slice) and 'graphy'. It enables visualization of a section of patient's anatomy by blurring other regions above and below the site of interest. For dental implant patients, high-quality complex motion tomography is required **[**3**]**.

Computed tomography

CT is a digital and mathematical imaging technique that creates tomographic sections. With latest CT scanners, images with sectional thickness of 0.25 mm can be obtained. This can be useful for determining the implant site in terms of bone density, and location of adjacent anatomic structures **[**4**]**.

Interactive computed tomography

This technique enables transfer of the imaging study to the clinician as a computer file. The clinician's computer becomes a diagnostic radiologic workstation with tools. An important element of ICT is that the clinician and radiologist can perform 'electronic surgery' (ES). With an appropriately designed diagnostic template, ES can be performed to develop the patient's treatment plan electronically in three dimensional. ES and ICT enable the development of three-dimensional treatment plans. Transfer of the plan to the patient at the time of surgery can be accomplished by the production of the computer generated, three-dimensional stereotactic surgical templates from the digital ICT and ES data **[**5**]**.

Cone-Beam Computerized Tomography

Use of CBCT is becoming increasingly popular and widespread among clinicians globally. This is moderately because of a new understanding of anatomic landmarks and structures, such as neurovascular canals and bundles, being at risk during implant placement.

Although CBCT is currently growing rapidly in popularity for imaging in the field of implant dentistry, and might even be considered as a primary imaging modality in selected cases, upcoming breakthroughs in research will probably bring new technologies that will again change the way in which we visualize hard and soft tissues for preoperative and postoperative evaluation of dental implants **[**6**]**. It uses a cone beam and reconstructs the image in any direction using special software. It gives all the information of a CT but, at one-eighth the radiation dose and at a lower cost. The software is used to display and visualize the anatomy in a way that is clinically meaningful. The manufacturers of CBCT scanners offer software that is capable of multiplanar reformations. Conventional CT scans take pictures of slices of the body (like slices of bread). These slices are a few millimeters apart.

The newer spiral (also named helical) CT scan takes continuous pictures of the body in a rapid spiral motion, so that there are no gaps in the pictures collected **[**7**]**.

Microtomography

Modification of CT, it is especially useful in acquiring serial sections of bone implant interface. Micro-CT is nondestructive, fast, and allows a fully three-dimensional characterization of the bone structure around the implant. Because of its high resolution, individual trabeculae can be visualized. The accuracy of micro-CT was qualitatively evaluated by comparing histological. Even very close to the interface, the titanium implant does not seem to produce significant artifacts. The technique provided high-resolution consecutive cross-sectional radiographic images of the specimens with a slice-to-slice distance of 4.4 to 11.0 µm.

Dentascan

Dentascan imaging provides programmed reformation, organization and display of the imaging study. The radiologist simply indicates the curvature of the mandibular or maxillary arch. The computer is programmed to generate referenced cross-sectional and tangential/panoramic images of the alveolus along with three-dimensional images of the arch. The cross-sectional and panoramic images are spaced 1 mm apart and enable accurate preprosthetic treatment planning.

Advances in implant materials

Ceramics implant material

High-strength ceramics used for implants are very inert in the body and exhibit minimal ion release. Aluminum oxide is regarded by many as the standard inert material as the remodeling of bony tissue adjacent to its surface is not altered by the presence of ions released or by immune reactions. The ionic ceramic surface is in a high oxidation state, thermodynamically stable and hydrophilic minimal ion release has been noted for aluminum oxide or zirconium oxide under normal conditions. Coatings may also include biologic coatings such as proteoglycans, bone morphogenetic proteins, and growth factors **[**8**]**. Zirconia is a ceramic material used in implantology because of biocompatibility (bioinert), superior esthetics (because its color is similar to the teeth), and mechanical properties, which are better than alumina. It can be used to produce an entire implant or as a coating. They have high resistance to corrosion, flexion, and fracture when contact with bone and soft tissue it is similar to that observed in titanium implants. **[**9**]**.

Carbon and polymeric implant surfaces

It has been shown to exhibit an inert and biocompatible surface when exposed to blood or tissue. The carbon structure used for dental implants is known as turbostratic and is a modified graphite structure. Polymeric surfaces are not commonly seen for dental implants. Designed to act as a shock absorber, but this polymeric element requires periodic replacement due to wear.

PEEK

A recent addition to the polymers being used as dental implant biomaterial is polyether ether ketone (PEEK). The major advantage of this material over titanium and zirconium is its elastic modulus (3.6 Gpa), which is closer to bone. Further, this material is being reinforced with carbon fibre so as to achieve a modulus of elasticity of 17.4 Gpa, which is close to cortical bone. Also, this material has better aesthetic properties as it allows transmission of light and is favourable in patients who are potentially allergic to titanium **[**10**]**.

Titanium-zirconium alloy

Straumann developed Roxolid that fulfils the needs of dental implantologists and is 50% stronger than cpTi. Ti-Zr alloys with 13%-17% zirconium (TiZr1317) have improved mechanical features for example better elongation and fatigue strength. Acid-etching and sandblasting on TiZr1317 with a monophasic configuration results in a topographically similar surface as on cpTi implants. Due to its excellent mechanical properties, thin implants and implant components that could be exposed to high strains is formed using titanium-zirconium alloy provided that the material displays a comparable decent biocompatibility as cpTi **[**11**]**.

Advances in Implant Surfaces

Modification of the implant surface has been studied and applied to improve biological surface properties favoring osseointegration **[**12**]**. The surface roughness of implants has been increased by various methods such as machining, plasma spray coating, grit blasting, acid etching, sandblasted and acid etching (SLA), anodizing, and biomimetic coating. The key factor in implant osseointegration is surface roughness, which shows increased osteoblast activity at 1 to 100 μm of the surface roughness compared to a smooth surface **[**13**]**. It is believed that rough surfaces have better osseointegration than smooth surfaces, but the results of the research have been diverse and it is not clear that multiple treatments provide better predictive results **[**14**]**.

The machined implant surface is the first-generation implant surface design with a turned surface implant. Plasma spray coating generally forms a thick layer of deposition such as hydroxyapatite (HA) and titanium by spraying a material dissolved in heat on the surface of the implant **[**15**]**. Grit-blasting is a process of spraying particles onto the surface of the implant using ceramic material or silica. Sand, HA, alumina or titanium dioxide (TiO2) particles are used and acid etching is performed to remove the remaining blasting particles **[**15**]**. Acid-etching is the roughening of the titanium implant surfaces using strong acids such as hydrofluoric acid (HF), nitric acid (HNO3), and sulfuric acid (H2SO4) or combinations of these acids. SLA is acid etching after sandblasting with 250–500 μm large grit particles. Anodizing is the dielectric breakdown of the TiO2 layer by applying an increased voltage to generate a micro-arc. This process forms a porous layer on the titanium surface **[**16**]**.

Advances in implant designs

All on four concept

The all on four for edentulous jaws has been developed to make the best use of available bone and to allow for immediate function using only four implants in edentulous jaws, the solution takes advantage of the benefits of tilting the posterior implants to provide a secure and optimal prosthetic support for a prosthetic bridge (even with minimum bone volume), that can be fabricated and functioning within just a few hours after surgery.

Zygoma implants

The zygomatic implant is an alternative to bone grafting in extremely resorbed maxilla where fixed prosthesis can be provided with four zygomatic implants with either a conventional two-stage procedure or a one-stage surgical procedure or flapless guided surgery. Although bone augmenting measures such as onlay grafts and sinus grafts are popular and well-documented, the four zygomatic implants procedure results in less morbidity, shorter delays between anatomical reconstruction and functional rehabilitation and can provide immediate or early loading with immediate function [17].

Mini-implants

Mini-dental implant (MDI) is in fact a trade name for the most widely used small diameter implant, the 3M ESPE MDI, the dental industry has adopted the term to describe this class of implants. Some small diameter implants are used as anchors in orthodontic cases and are called temporary anchorage devices. One example of a temporary anchorage device is the Unitek Temporary Anchorage Device System. These vary from the more common MDIs in that they are removed after they are no longer needed and orthodontic treatment is completed [18]. It is important to note that the pull out strength of an implant has been shown to be based on its length rather than its diameter [19]. Multiple tip, thread, body, and head designs are available in the category as well. The majority tip designs are sharp or slightly blunted to provide the self-tapping ability of the implant to the medullary bone. Thread designs vary from thin to thick and thread spacing is also variable.

The design variations allow for use of the implants in the different densities of bone (D1, very dense; D2 and D3, soft) found throughout the mouth. Fixed crowns or bridges can be cemented directly to the square or cubic head of the mini. Subsequently, a sphere was milled into the square portion of the head allowing for a more elegant restorative solution. This 'o-ball' design became a popular solution to secure loose dentures. These are available in lengths of 6, 8, 10, 13, 15, and 18 mm and are inserted directly through the overlying gingiva and into the bone beneath, there is no need to surgically cut and raise the overlying flap. A single minimally invasive surgery is needed for insertion of MDI. Immediate loading can be done due to their self-tapping design.

Short implant

In an atrophic alveolar ridge, there are many anatomical limitations (maxillary sinus, nasal floor, nasopalatine canal, inferior alveolar canal) that make placement of a standard implant difficult. To overcome these limitations and vertical bone deficits, additional surgical procedures, such as guided bone regeneration, block bone grafting, maxillary sinus lift, distraction osteogenesis, and nerve repositioning, are performed to place a standard implant. However, the procedure is sensitive, challenging, costly, and time-consuming and increases surgical morbidity and causes many complications such as sinusitis, infection, hemorrhage, nerve injury, and gait disturbance. **[**10**]** Short implants are considered to be simpler and more effective by reducing the likelihood of such complications, patient discomfort, procedure costs, and procedure times in rehabilitation of the atrophic alveolar ridge.

Transitional implants

Their diameter ranges from 1.8 to 2.8 mm and length ranges from 7 to 14 mm. Transitional implant are fabricated with pure titanium in a single body with treated surface. There primary function is to absorb masticatory stress during the healing phase, ensuring stress free maturation of bone around the submerged implants and allowing them to heal uneventfully.

Contraindicated when depth of supporting bone is less than 10 mm with an insufficient cortical bone to provide implant stabilization, patients with excessive bruxism, when placement of sufficient number of transitional implants is not possible [21].

One-piece implants

Abutment and implant body in one piece and not separate; they are commercially available in 3 mm diameter and 12, 15 and 18 mm length. They have unique properties such as: (a) maximum strength – minimum profile. It is one-piece, titanium alloy construction provides maximum strength, while its 3.0 mm diameter allows placement in areas of limited tooth-to-tooth spacing. The one piece 3.0 has been shown more strength when loaded to failure than other implants less than 4 mm in diameter. (b) Minimal surgery – maximum esthetics. Because one-piece implants are placed using a single-stage protocol, the soft tissue experiences less trauma than typical two-stage protocols. The long-term treatment of missing maxillary laterals and mandibular incisors, for treatment of spaces that cannot be handled with larger two-piece implants also used for over dentures [22].

Custom implant using three-dimensional printing

Custom implant using three-dimensional printing (3DP) was first used in the fields of rapid tooling and rapid prototyping. Initially, specifically single, personalized objects were manufactured by 3DP in restorative dentistry. By combining oral scanning with a CAD/CAM design and using 3DP, dental labs can produce dental prostheses (crowns, bridges) and plaster/stone models more rapidly and with excellent precision than most tradition procedures performed by lab technicians [23].

With the advancement of implant dentistry, there was an increase in utilizing CAD/CAM as a supportive means to maximize the results of implant treatment. Customized implant abutments have been successfully produced using CAD/CAM for difficult cases when standard abutments may not provide a suitable option for a future prosthesis. Thus, to combine with customized abutments, customized coping was also manufactured for such cases to provide a more accurate impression [24].

The use of cone beam computed tomography (CBCT) combined with CAD/CAM was suggested to produce a surgical guide for implant placement. Mini-implants were used as reference points. A software created the three-dimensional simulation and allowed the clinician to plan an ideal implant placement, virtually integrating the future prosthetic for a complete rehabilitation treatment. A digital file of the surgical template was exported, and fabrication of surgical guide was performed by 3DP .

Advances in Implant Impression Materials and Techniques

A newer impression material Vinylpolyethersilicon (VPES) which is amalgamation of vinylpolysiloxane(VPS) and polyether(PE) has been developed which according to the manufacturer has intrinsic hydrophilicity and excellent dimensional stability. Nevertheless, the information regarding its accuracy is inadequate and studies done using VPS, VPES and PE to evaluate the accuracy and reproducibility by 3D analysis does not show significant difference in terms of spatial deviation **[**25**]**.

Digital implant impression

More recently, one of the major developments in implant prosthodontics has been the adoption of engineering principles in the form of computer-aided design and computer aided manufacturing (CAD/CAM) to construct implant prosthesis. This technology utilizes 3D intraoral scanners which has revolutionizing the way we take impressions. The digital implant impression technique has proven its possibilities as an effective alternative for the analogue impression-taking technique. Advantages of the digital impression are improved patient acceptance, reduced distortion of impression materials, previsualization of the preparation three dimensionally, virtual assessment of the implant prosthetic space, depth of restorative interface, emergency profile configuration before proceeding with laboratory steps, potential cost and time effectiveness **[**26**]**.

Miratray implant advanced tray

The Miratray Implant Tray simplifies the process of taking open tray implant impressions. The tray is provided in three maxillary and three mandibular sized trays and the trays are unique in their design. The occlusal surface is covered by a transparent foil. This allows identification of the heads of the pins easily intraorally. Retention slots and an internal rim provide mechanical retention to retain the impression material within the tray. Should the practitioner choose to supplement the retention with a PVS adhesive, it is recommended that it is not applied to the foil surface as this may obscure visualization of the pins when inserting the tray to proper depth. Additionally, it should be noted that PVS adhesive does not adhere to putty PVS materials and does not therefore increase retention of the impression material to the interior of the tray. The PVS adhesive does adhere to all other PVS viscosities.

The technique involves filling the tray with an appropriate impression material, the author recommends either a universal body PVS or a tray or putty PVS. The tray is then inserted over the open tray impression heads intraorally and pressed down crestally until the top of the impression pins are visible through the transparent foil. The practitioner then presses the tray further until the pins puncture the foil and are visibly protruding through the foil. This contains the impression material within the tray without the potential problem often seen with use of custom or modified stock trays of the impression material obscuring the tops of the pins. Upon setting, the pins are rotated in a counter clockwise fashion and removed from the impression and the impression is removed intraorally. Due to the design of the tray, it can be used in all implant impression situations whether the arch is partially dentate or fully edentulous.

Advances in robotics in implantology

The robotic system mirrors the development of the mandible and the contact forces of occlusion to make it feasible for different implant methods and designs to be tried and assessed prior to animal testing or human clinical trials. This innovation of robot implant denture from preparatory planning to immobilize drilling was built up in France by Ecole des Mines de Paris. This technique comprises of shaping pre-modified programming and is utilized to work with CT scanner information.

Presently a 3D model of jaw of the patient is made, implants installations are set and then a precise robot is utilized to drill a jaw splint in the foreordained areas to create a guide for surgery. The robot has 3 translations and 2 rotations [128,129]. In Portugal, an alternative framework utilizing the ABB IRB2400/M98 robot is recognized by the University of Coimbra.

The framework is satisfactorily prepared and incorporates modern robot controller, an information acquisition board, strain measures and a torque sensor. This plays out the implant drilling protocols and applies force on the accumulated inserts to imitate rumination process [27].

A system of implant surgery proposed by the University of Duesseldorf comprises of a robot arm, driver shafts, torque sensors, angle sensors, a precision potentiometer and mini-inserts in the bone. It is essentially concerned about effect of insertion angle, depth and stability of the diameter of the mini-inserts [28].

Conclusion

Implant dentistry empowers the restoration of almost every clinical circumstance ranging from partially to completely edentulous patients with more prominent achievement and expectedness. With all the advancements that have been made so far in the field of implantology, the objective still remains to rearrange the current strategies further, decrease the period of implant treatment for both the patient and the clinician, make the treatment cost-effective and ad-lib the success rate. Endeavours to accomplish this objective alongside an intensive preparing of the dental experts to execute as a group and long-term maintenance by the patients doubtlessly makes implants the eventual fate of dentistry.

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