REVIEW ARTICLE

Revolutionizing Restorative Dentistry: An Overview

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Abstract The field of science and research is ever changing and the scientific discipline of prosthodontics is no exception. The practice of prosthodontics and the supporting technology involved has evolved tremendously from the traditional to the contemporary. As a result of continual developments in technology, new methods of production and new treatment concepts may be expected. Clinicians must have certain basic knowledge if they are to benefit from these new procedures. This article reviews the contemporary trends in the field of prosthodontics and provides an insight into what one might expect in the near future.

Keywords Digital dentistry · CAD-Cam · Technology · Virtual · Future

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Introduction

Prosthodontics as a specialty can stake its claim as one of oldest dental specialties and has a long history of innovation and adaptability. It can be dated back to the eighth century when dentures were carved from a single piece of wood [1]. With further progress, impression materials developed with the use of waxes and plaster of paris. From gold denture bases, porcelain and then vulcanite dentures in the eighteenth century to the introduction of acrylic resins, elastomeric impression materials and mechanical instruments for tooth preparation in the nineteenth century- it has been a long journey [2]. With the passing years and the endless growth in research, removable and fixed prosthodontics were established as the two main treatment modalities.

Prosthodontics, perhaps more than any other dental specialty, has shown itself capable of evolution in response to changing needs and will probably continue to change. Considering the current trends, the main focus in prosthodontics has shifted from removable dentures to fixed prostheses, while implant-supported restorations have attracted immense interest in the dental community. The increasing and fast paced progress in the implant field along with the rapid progress made in the area of radio imaging and diagnosis has already made implants a predictable and viable restorative option. The trend in dentistry is utilizing technology to make it more comfortable, durable, efficient and natural-looking for the patient. With the advancements in technology, even the conventional complete dentures may soon be replaced by the computer-assisted designed and computer-assisted manufactured (CAD/CAM) dentures.

But is it the future? One can never say. As the technology is progressing at a rapid pace, one cannot say

whether the newly developed procedures will become obsolete even before it can be used in general practice. With the major strides and advances in stem cell research and bio engineering, the days of a bio engineered tooth replacement may not be far away. Ultimately, the nanorobotic manufacturing and installation of a biologically autologous tooth including both mineral and cellular components, may become feasible to undertake within the time and economic constraints of an ordinary dental office visit. Hence, the purpose of this article is to explore the many facets of advancements in prosthodontics and predict on its future trends.

Search Strategy

An electronic search was performed of articles on MEDLINE from 1990 to June 2013. Key words such as digital, technology, advances, virtual, cad cam were used alone or in combination to search the database. The option of "related articles" was also utilized. Finally, a search was performed of the references of review articles and the most relevant papers.

Digital Dentistry

Digital dentistry may be broadly defined as any dental technology or device that incorporates digital or computer-controlled components in contrast to that of mechanical or electrical alone. During the 1980s, a growing interest in technology for the dental office developed. Practitioners realized how the incorporation of computers could lighten the load of busy practices while affecting productivity in substantial ways. They acted as centralized databases mainly used by front desk personnel. With time, technology started to include clinical features in addition to data and financial management functions. In the mid 1990s, the appearance of the intraoral camera resulted in computer monitors moving into the operatory. Today's software choices have successfully combined administrative functions along with clinical features, thereby augmenting the role of chairside computers [3].

Digital dentistry is opening new arenas in dentistry. As the trend continues, digitization will become an integral part of contemporary prosthodontics with the probability of most of the procedures being based on digital techniques in the near future [4]. The use of CAD-CAM technology, rapid prototyping, stereolithography, virtual articulators and digital facebows, digital radiographs (including CBCT), digital shade matching are all examples of digitization in dentistry. Further, computer-aided implant dentistry including the design and fabrication of surgical guides are fast becoming an integral part of clinician's practice.

The field of training, education and research by the use of virtual patient programs, dental softwares and audiovisual aids are the other available options. Digital patient education is growing rapidly. Virtual reality dental training [5] has been developed in which students have access to virtual oral cavities to practise on 3D virtual-reality jaws. The students need to wear glasses which produce a 3D jaw on the computer screen. Panels on the edge of the glasses, and a head tracking camera, allow the jaw image to move relative to the student's head position, allowing them the real-world experience of examining the teeth from different angles. Furthermore, the drills and other instruments are based on 'haptics', a tactile feedback technology through which the user can sense touch and force in a virtual-reality environment. The advantages offered by such a simulation system include effective learning without any fear of making mistakes on a patient, possibility of repeating various dental operations, ease of evaluating student performance, and low-cost dental training even without an instructor.

The virtual reality (VR) system most often used, the DentSim (DenX Ltd., Australia), has the added capability of evaluating students' preparations through the use of computer tracking. Studies assessing DentSim technology found that students learn at a faster rate, developing their skills in significantly less time [6, 7]. However, a study conducted by Quinn et al. [8] compared the training received by students from only the VR system to conventional instruction and/or a combination of VR and conventional indicated that VR should not be used without supplemental faculty instruction.

Another study compared the efficacy of a virtual reality computer-assisted simulation system (VR) with a contemporary non-computer-assisted simulation system (CS). Although, there were no statistical differences in the quality of the tooth preparations, CS students received five times more instructional time from faculty than did VR students. The authors concluded that while further study is needed to assess virtual reality technology, this decreased faculty time in instruction could impact the dental curriculum [9].

CAD-CAM Aided Restorations

During the last decade, CAD/CAM has become popular in dentistry, and has been used to fabricate inlays/onlays, crowns, fixed partial dentures and implant abutments/prostheses [10]. Dental technology that used to be centred on the standardized lost-wax casting technology has been greatly improved with the introduction of dental CAD/CAM systems. CAD/CAM has transformed the fabrication of dental prostheses-offering improved accuracy, longevity,

and biocompatibility; along with reduced labor costs and fewer complications than casting technologies. However, these advantages must be balanced against the high initial cost of CAD/CAM systems and the need for additional training.

Boeckler et al. [11] evaluated CAD/CAM titanium ceramic single crowns after 3 years in function. They concluded that the clinical performances of the CAD/CAM titanium ceramic crowns for 3 years were acceptable, with no biologic complications and a high cumulative survival rate. Therefore, the CAD/CAM titanium ceramic crowns may be an affordable substitute for a conventional high noble metal ceramic crown.

A systematic review [12] sought to determine the long-term clinical survival rates of single-tooth restorations fabricated with CAD/CAM technology. The authors reported that the long-term survival rates for CAD/CAM single-tooth Cerec 1, Cerec 2, and Celay restorations appeared to be similar to the conventional ones. However, no clinical studies or randomized clinical trials reporting on other CAD/CAM systems currently used in clinical practice and with follow-up reports of 3 or more years were found at the time of the search.

Kapos et al. [13] systematically evaluated the existing scientific evidence on human clinical studies describing the application of computer-aided design/computer-assisted manufacturing (CAD/CAM) technology in restorative implant dentistry. They concluded that clinical studies on the use of these techniques were too preliminary and underpowered to provide meaningful conclusions regarding the performance of these abutments/frameworks.

Another systematic review by Abduo et al. [14] analyzed the published literature investigating the accuracy of fit of fixed implant frameworks fabricated using different materials and methods. The investigated fabrication approaches were one-piece casting, sectioning and reconnection, spark erosion with an electric discharge machine, computer-aided design/computer-assisted manufacturing (CAD/CAM) etc. The authors concluded that till date, CAD/CAM was the most consistent and least technique-sensitive of these methods.

The technology is currently at a stage where CAD/CAM dental restorations can be created to similar functional standards as their conventional counterparts. However, it is clear that these newer developments await longer-term studies before recommendations can be made. Although the evidence to date suggests that restorations produced by CAD/CAM are an acceptable alternative to their conventionally made equivalents, they are not significantly better. Patient expectations, financial constraints and operator preference, as well as the availability of CAD/CAM systems, will dictate the suitability of this type of restoration on an individual basis in the future [15].

All CAD/CAM systems consist of three different components:

1. A digitalisation tool/scanner that transforms a present geometry into digital data that can be processed by the computer. A clinical study conducted by Syrek et al. [16] compared the fit of all-ceramic crowns fabricated from intraoral digital impressions and conventional silicone impressions. It was found that the crowns fabricated with intraoral scans had good marginal fit and tended to have optimal interproximal contact area with respect to size and contact pressure to adjacent teeth.

   There are two different types of scanning-

   (a) Direct intraoral scanning-In this, the data is obtained directly from the prepared tooth which circumvents the need to take an impression and pour a stone cast. This eliminates two of the steps which can influence the accuracy and precision of the final result. However, intra-oral scanning requires the use of an optical digitizer: the tissues to be digitized must be opaque and this is achieved by application of titanium oxide. This procedure alters the geometry of the surfaces and may compromise the exactness of the internal fit [17]. The main direct image acquisition systems available are: CEREC Bluecam (Sirona), Lava COS System (3M ESPE), iTero System (Cadent/Straumann), and E4D System (D4D Technologies). Ender et al. conducted a study to compare the accuracy (trueness and precision) of digital impressions of the full arch with that of conventional impressions on the in vitro model. The digital impressions were made with the Cerec AC Bluecam and the Lava COS system. The authors concluded that the accuracy of the digital impression was similar to that of the conventional impression [18].

   (b) Indirect mechanical scanning- In this, the master cast is read mechanically line by line and is distinguished by its high scanning accuracy. The drawbacks of this system are long processing time and high expenditure compared to optical scanners Eg-Procera.

      A recent in vitro study [19] compared the accuracy of direct and indirect digitalization by comparing construction datasets using a new methodology. Twelve test datasets were generated in vitro and were scanned by three different methods (1) with the Lava Chairside Oral Scanner (COS) (2) by digitizing polyether impressions and (3) by scanning the referring gypsum cast by the Lava Scan ST laboratory scanner (ST) at a

time. The authors concluded that direct digitalisation with Lava COS showed statistically significantly higher accuracy compared to the conventional procedure of impression taking and indirect digitalisation. However, in an another study, Flugge et al. [20] evaluated the precision of digital intraoral scanning (iTero) under clinical conditions and compared it with the precision of extraoral digitization (D250). They concluded that scanning with the iTero was less accurate than scanning with D250. Intraoral scanning with the iTero was less accurate than model scanning with the iTero, suggesting that the intraoral conditions (saliva, limited spacing) contributed to the inaccuracy of a scan.

2. Software that processes data and depending on the application, produces a data set for the product to be fabricated.
3. A production technology that transforms the data set into the desired set [21].

Depending on the location of the above components of the CAD/CAM systems, three different production concepts can be employed [22]:

First concept is that of laboratory production- In this, the dentist sends the impression to the laboratory where a master cast is fabricated first. The remaining CAD/CAM production steps are carried out completely in the laboratory.

The second production concept used is that of Chairside Production- Dental CAD/CAM has evolved over the past 25 years with the development of chairside restorations, beginning with CEREC and most recently the E4D Dentist System. All components of the CAD/CAM system are located in the dentist's office. Fabrication of dental restorations can thus take place at the dentist's chair without the help of a laboratory. It offers dental professionals and their patients the convenience of single visit dentistry. Thus, it is now possible for patients to present with a condition requiring restorative treatment, have their tooth prepared and digitally scanned/imaged (as opposed to having a traditional impression taken) and have a final restoration seated in the same day.

Results with in-office milling machines appear to be as good as those from laboratory milling machines. A systematic review of 16 articles that comprised 1,957 restorations found no significant differences in 5-year survival rates between chairside CEREC (90.2–93.8 %) and Celay laboratory restorations (82.1 %) [12].

Lastly, Centralised fabrication in a Production Centre is another option in relation to fabrication of such a restoration. 'Satellite scanners' in the dental laboratory can be connected with a production centre via internet. Data sets produced in the dental laboratory are sent to the production centre for the restorations to be produced with a CAD-

CAM device. Finally, the production centre sends the prosthesis to the respective laboratory. Such networked production systems are currently being introduced by a number of company's worldwide [23]. Advantage of this centralized production is that it requires less investment, since only the digitalisation tool and software have to be purchased while still having access to a high-quality production process. In addition, there is no dependence on a particular production technology (e.g. milling technology).

Another advancement in the above process is the complete elimination of dependence on the dental laboratory. After the scanning is completed at the chairside, the digital data can be sent directly to the production centre for milling, thus reducing the production time.

An important limitation of CAD/CAM system with the existing software is that it cannot take into consideration the functional movements, so the occlusal surface of the prostheses has to be manually trimmed to these movements in the mouth or in an articulator. Therefore, one area for improvement would be representation of jaw movement using CAD/CAM; current design software only captures shapes [24]. Taking CAD/CAM to the next level, virtual articulators can be integrated into it during the fabrication of the prostheses.

Virtual Articulators

Virtual articulators are also called as 'SOFTWARE articulators'. They are not real or tangible but exist only as a computer program. They comprise of virtual condylar and incisal guide planes. Guide planes can be measured precisely using jaw motion analyser or average values are set in the program like average value articulator. The reproduction of dynamic occlusion in the mechanical articulator has clear restrictions inherent to the process, but also caused by biological variability. Virtual articulators can expediently supplement mechanical articulators, since with them it is possible to display in relation to time unusual and extraordinary perspectives, such as sectional images and flowing, sliding contact points. The virtual articulators are able to design a prostheses kinematically. They are capable of:

– simulating human mandibular movements,
– moving digitalized occlusal surfaces against each other according to these movements and
– correcting digitalized occlusal surfaces to enable smooth and collision-free movements [25].

In a recent review, studies published in the literature on the design, functioning and applications of virtual articulators were analyzed. The virtual articulator could simulate the specific masticatory movement of the patient. During mandibular animation, the program calculates the sites where the opposing teeth come into contact. The studies

made to assess the reliability of the virtual articulator showed good correspondence in visualization of the number and position of the dynamic contacts. The authors concluded that the virtual articulator is a precise tool for the full analysis of occlusion in a real patient [26].

Presently, the technology of virtual articulators is only a supplement to the mechanical articulators for better visualization of the occlusion. In near future, with further advances in this technology, they may be regarded as a core tool in many diagnostic and therapeutic procedures and in the CAD/CAM manufacture of dental restorations.

Discussing about occlusion, another technology in this respect is the introduction of T-scan for computerized occlusal analysis. The T-scan is a diagnostic device that measures relative biting forces, including occlusal force, timing and location. The occlusal contact forces are perceived and analyzed using paper-thin, disposable sensors. The occlusal contact data is then transferred to the computer and presented in a dynamic movie format in vivid, full-color 3-dimensional (3-D) or 2-dimensional graphics. This enables the clinician to dynamically visualize the patient's bite which helps to locate occlusal interferences, adjust the occlusion, and hence provide better restorative service. It provides a higher degree of precision in functionally balancing teeth and positively influences muscular activity. An additional feature is the Patient File Management system, which helps in storing patient records and retrieving them as and when required.

Digital Complete Dentures

Although CAD/CAM has established itself in the field of fixed prosthodontics, in the near future this technology is likely to be applied for complete dentures. It is anticipated that the fabrication of complete dentures with CAD/CAM technology will become a common practice. The clinical technique is different from conventional complete denture methods in that it requires impressions that record the shape of both the intaglio and cameo surfaces of complete denture bases while also identifying muscular and phonetic locations suitable for the placement of prosthetic teeth. This information can then be scanned and transferred to a CAD software program. The casts are created and articulated virtually and denture teeth are virtually arranged into appropriate positions in the virtual denture base. The resulting data (denture base form and tooth arrangement morphology) can then be exported to a milling machine for fabrication of the dentures [27].

The advantages of this procedure are

1. Clinical chairside time is reduced considerably. It is possible to record all the clinical data for complete dentures in one appointment (1–2 h).

2. CAD/CAM precision and accuracy.

3. A repository of digital data remains available that allows for more rapid fabrication of a spare denture, a replacement denture, or even a radiographic or surgical template that aids in the planning and placement of dental implants in the future [28].

Bidra et al. analyzed the existing literature on computer-aided technology for fabricating complete dentures. The authors stated that significant advancements in this technology have currently resulted in their commercial availability with shorter clinical protocols. Although no clinical trials or clinical reports were identified in the scientific literature, the Google search engine identified two commercial manufacturers in the United States currently fabricating complete dentures with computer-aided design and computer-aided manufacturing (CAD/CAM) technology for clinicians world-wide. However, they concluded that prospective clinical trials with true clinical endpoints were necessary to validate this technology [29].

The above CAD/CAM aided fabrication method can be further improved upon by the introduction of virtual tryin (digital) of the patient. A digital facial image of the patient can be constructed by imaging techniques. The software program would provide three to five suggestions for the size, shape and colour of the teeth. The teeth can then be virtually adjusted according to their most pleasing and suitable positions as selected by the dentist.

Prevalence of CAD CAM in India

The Indian dental prosthetics market remains largely traditional. Crowns and bridges in India feature a low rate of CAD/CAM penetration, generally a result of the large initial investment required on the part of laboratories. The domestic market also features low labor costs, which makes it more difficult to justify investment in CAD/CAM technology. However, over the forecast period, use of CAD/CAM technology will grow substantially, largely due to declines in prices of milling machines and CAD/CAM scanners.

The Indian dental market is expected to experience both rapid increases in the crowns and bridges market and a low but stable growth rate in the denture market.

Additive Manufacturing

Most of the current methods using CAD/CAM fabrication techniques in dentistry have concentrated on milling from a solid block of material (i.e. subtractive manufacturing). However, this method of manufacturing is very wasteful as more material is removed compared to what is used in the

final product. Another limitation of these systems is that the process does not easily lend itself to mass production such as crowns and bridges, since only one part can be machined at any one time [30]. Considering the limitations, in the near future one can expect a major transition from making prostheses by subtractive manufacturing to what is referred to as additive manufacturing. Additive manufacturing processes were traditionally used to make prototypes or models and thus it had its origin in rapid prototyping (RP).

Rapid Prototyping (RP)

Rapid prototyping is used to describe the customized production of solid models using 3-D computer data [31]. As mentioned above, it operates on the principle of depositing material in layers or slices to build a model (additive technique). The primary advantage of this process is that the model created directly retains all the details of the internal geometry rather than just the outer surface contours [32]. Additive manufacturing/rapid prototyping is a relatively new tool and has been used in the production of molds for facial prostheses [33]. Data used by RP machines can be obtained from medical imaging techniques such as computed tomography (CT), magnetic resonance imaging (MRI), or laser imaging scans. These digitized technologies allow parts of the body to be serially recorded, which can then be 3-dimensionally rendered and manipulated to generate accurate models [34]. Several studies have analyzed the dimensional accuracy of anatomic models produced by rapid prototyping systems [35–37]. Barker et al. [34] compared measurements between anatomic landmarks on a dry skull with an anatomic replica and noted an absolute mean deviation of 0.85 mm. They concluded that models could be confidently used as accurate 3-D replicas of complex anatomic structures. Choi et al. [35] found that the absolute mean deviation between 16 linear measurements made on a dry skull and an RP model to be 0.62 mm. Bill et al. [36] determined that an accuracy of 0.5 mm can be reached for anatomic models based on CT data.

The basic methodology for all the current rapid prototyping techniques can be summarized as follows:

1. A CAD model is constructed which is then converted to STL (standard triangulation language) format.
2. The RP machine processes the STL file by creating sliced layers of the model.
3. The first layer of the physical model is created. The model is then lowered by the thickness of the next layer, and the process is repeated until completion of the model.
4. The model and any supports are removed. The surface of the model is then finished and cleaned.

The major rapid prototyping technologies which can be used are [38]:

1. *Stereolithography* (SLA, the first rapid prototyping technique) which builds models by laser fusing a photopolymer layer by layer. The advantages of SLA are the high geometrical accuracy of 0.1 mm, which is better than the spatial resolution of the imaging process and the transparency of the used material. However, a major disadvantage of SLA technology is that it can only fabricate resin prototypes of facial prostheses, which cannot be directly used for laboratory processing [31]. Thus, one must replicate the resin prototypes in a wax pattern using conventional dental impression/replication methods.
2. *Selective Laser Sintering* (SLS) which selectively fuses thin layers of meltable powders to previously fused layers. Unlike SLA, SLS technology generates direct solid wax patterns instead of resin patterns from wax powder or polystyrene powder [38]. The manufacture time is reduced and its cost is less. Another advantage of this technique is the variety of thermoplastic powders which can be used and a geometric accuracy within 10 μs [39].
3. *Fused Deposition Modeling* builds up objects in layers by the extrusion and solidification of melted filaments. There is a choice of materials and even different colors. This allows the reproduction of more than one anatomical structure in one model distinguishable by color [30].
4. *3D Printing* which selectively deposits binding material through a print head to fuse a thin layer of powder to a previously fused layer. Another variation of this includes the polyjet range of printers from Objet [40] (a commercially available inkjet printing technology). They build the model layer by layer by depositing droplets of a polymer and as each layer is formed, it is cured by UV light (as opposed to binder mentioned above).

In a study conducted by Ibrahim et al. [40] the capacity of Selective Laser Sintering, 3D Printing and PolyJet models to reproduce mandibular anatomy and their dimensional error was analyzed. The authors concluded that the SLS prototype had a greater dimensional accuracy than the PolyJet and 3DP models. However, the PolyJet model was the most accurate technique in the reproduction of anatomic details of the mandible, followed by the SLS and 3DP.

Another study was undertaken to compare the dimensional accuracy and surface details of three prototype models with a 3D STL (standard template library) image. The three different rapid prototype models were; model 1-fused deposition model (FDM) using ABS (acrylonitrile

butadiene styrene), model 2-Polyjet using a clear resin and model 3—a 3 dimensional printing using a composite material. Measurements were made at various anatomical points. For surface detail reproductions the models were subjected to scanning electron microscopy analysis. The authors concluded that the dimensions of the model created by Polyjet were closest to the 3D STL virtual image followed by the 3DP model and FDM. SEM analysis showed uniform smooth surface on Polyjet model with adequate surface details [41].

Although there have been rapid developments in these technologies, there is a dire need for refinement and development of the software along with the equipment for dental requirements and for further studies in this area.

Digital Removable Partial Dentures

Machining of complex-shaped, thin-walled metal plates, bars, or clasps required for a removable partial denture is difficult to achieve. The problems of securing the workpiece to the bed of the milling machine and deflection of the thin-walled workpiece under machining load are well documented in the machining industry [42]. Thus, additive manufacturing/rapid prototyping can be used for the fabrication of digital removable dentures.

Recent work has shown that, in principle, RP technologies can be successfully applied to the fabrication of removable partial denture (RPD) alloy frameworks [43]. Williams et al. [44] have described a case report on the first patient-fitted chromium cobalt removable partial denture framework produced by CAD/CAM and rapid prototype technologies. Once the dental cast is scanned, virtual surveying and design of the framework on a 3-dimensional computer model is accomplished. A rapid prototype machine (SLS) is used for direct fabrication of the alloy framework. Traditional finishing techniques are applied, the framework is assessed by a clinician in a conventional manner and fitted to the patient.

Rapid Prototyping in India

Though rapid prototyping may have been utilized in various fields in India, but considering the field of dentistry it is still in its infancy. Rapid prototyping techniques have been used in dental therapy, mainly for the fabrication of models to ease surgical planning in implantology, orthodontics, and maxillofacial prostheses. On the other hand, the application of these technologies associated with 3D-virtual models in dental education is still awaited, once they have significant potential to complement conventional training methods.

Virtual Treatment Planning In Implant Dentistry

In less than 25 years, the principle of osseointegrated implants has revolutionized the treatment of partially and totally edentulous patients. With a trend in an increasing awareness on implant dentistry, the urban prosthodontic practice is likely to see an immediate shift in more implant related practice with a relative decline in contemporary crown and bridge prosthodontics.

Computer-guided surgery has made this field more exciting and predictable for the future. The limitations of conventional pre-implant treatment planning, which is based among other data on 2D radiographs, have been over-passed, to a certain extent, by CT or CBCT scan technologies and computer software systems and tools. With the advent of CBCT imaging, hard and soft tissues can be visualized in 3D while exposing the patient to only relatively low doses of radiation. It allows for an unprecedented three dimensional evaluation of each patient's individual anatomy. Once the scan is taken, it can be viewed on the computer workstation using the native software (i.e. i-CAT Vision) or the DICOM data can be exported into an interactive treatment planning software such as Simplant,Nobel Guide,coDiagnostiX, Easy Guide etc. [45].

These 3D planning softwares allows an undistorted visualization of the jaw bone in four views: axial,cross-sectional, panoramic and 3D reformatted reconstructions. Exact virtual representations of the implants, abutments and other surgical accessories can be inserted into the 3D scene and positioned in the precise 3D coordinates that the clinician deems appropriate [46]. Thus, they allow for implant placement plans that can then be transferred to the patient with the help of a surgical template. Once the computer simulation is completed, it is saved as a "sim" file and sent to the processing center via e-mail. At this stage, a rapid prototyping machine using the principle of stereolithography is employed to fabricate the stereolithographic models [47]. Sarmant et al. compared the accuracy of a conventional surgical guide to that of a stereolithographic surgical guide. They concluded that within the limits of the study, implant placement was improved by using a stereolithographic surgical guide [48].

A systematic review was also conducted to analyze the dental literature regarding accuracy and clinical application in computer-guided template-based implant dentistry. A high implant survival rates were found ranging from 9 to 100 %. However, a considerable number of technique-related perioperative complications were observed. The authors suggested that future research should be directed to increase the number of clinical studies with longer observation periods and to improve the systems in terms of

perioperative handling, accuracy and prosthetic complications [49].

Another systematic review by Jung et al. [50] assessed the literature on accuracy and clinical performance of computer technology applications in surgical implant dentistry. Differing levels and quantity of evidence were available for computer assisted applications. High implant survival rates after only 12 months of observation and a reasonable level of accuracy were obtained. Future long term clinical data are necessary to identify clinical indications and justify additional radiation doses, efforts and costs associated with computer assisted implant surgery. The authors concluded that there was not yet evidence to suggest that computer assisted surgery is superior to conventional procedures in terms of safety, outcomes, morbidity and efficiency.

Additionally, a new computer-aided design/computer-aided manufacturing (CAD/CAM) system has been introduced with specifically designed two-piece healing abutments (BellaTek Encode; Biomet 3i, Palm Beach Gardens, Fla) that incorporate occlusal codes recognizable by laser scanners. Laser optical scanning interprets these codes and enables the design of the appropriate abutment in CAD software. These coded abutments eliminate the need for impression copings as they provide the information necessary for the ideal anatomic design of the definitive custom abutment (implant depth, hexagon-orientation, platform diameter, Certain Internal Connection or External Connection interface). The virtual abutment is milled to the precise design from solid titanium alloy, and the milled titanium abutment is then related to the implant analog in a cast poured with dental stone [51]. Eliminating the latter step, another technique has been developed using CAD (Robocats Technology; Biomet 3i) to drill a hole in the definitive cast, and create a space into which the implant analog is placed. This technique makes it is no longer necessary to make a second implant-level impression [52].

Combining the above technology with digital oral scanning has the potential to further simplify the time between impression-making and delivery of a definitive restoration, and it offers additional benefits to both patients and clinicians. In a clinical report by Nayyar et al. [53], the use of an intraoral scanner (Lava COS; 3M ESPE) along with digitally coded healing abutments (BellaTek Encode System; Biomet 3i) for the fabrication of implant-supported, cement-retained restorations have been described. The impressions of coded healing abutments were made by using a digital intraoral scanner. The codes of the healing abutments informed the proper design and milling of the custom abutments with computer software. Stereolithography models were also generated by using the scan data and abutment design files and were used to fabricate cement-retained, metal ceramic restorations. The removal of healing abutments, use of impression copings, impression materials, and dental stone were unnecessary with the presented technique.

Softwares for treatment planning in dental implantology are commercially available and techniques for fabricating surgical jigs have been developed, leading to expectations that much of the process from recording impressions digitally, to implant placement and superstructure fabrication may take place in a digitized environment.

Nanotechnology

Nanotechology is the manipulation of matter on the molecular and atomic levels. It is measured in the billionths of meters or nanometer, roughly the size of two or three atoms. Genesis of this concept is based on the fact that microstructures or tiny nanorobots can be manufactured and utilized in human body for treatment of various diseases by restoring cellular functioning at molecular level [54].

Application of nanotechnology to dentistry has been a novel area of interest since some years now and has led to the materialization of a new field called nanodentistry. Preservation and maintenance of oral health utilizing nanodentistry will be made possible by employing nanomaterials, biotechnology including tissue engineering and nanorobotics. Nanorobots might use specific motility mechanism to crawl and swim through human tissues with navigational precision. These nanorobots will acquire energy, sense and manipulate their surroundings and pass through the odontoblastic process without disrupting the cells. Their functions may be controlled by an onboard nanocomputer that executes preprogrammed instructions in response to local sensor stimuli. Alternatively, the dentist may issue strategic instructions by transmitting orders directly to in vivo nanorobots via acoustic signals or other means [55].

Most importantly, nanodental techniques for major tooth repair may evolve through several stages of technological development, first using genetic engineering, tissue engineering and regeneration, and later involving the growth of whole new teeth in vitro and their installation. These advances are still in the developmental stage and are not yet commercial realities [56]. Perhaps, future "restorative materials" will merely be temporary "bandages" protecting underlying substances that, over time, will slowly remineralize decayed tooth structure.This will eventually, lead to the intraoral development of an intact, functioning tooth once again, instead of replacing missing tooth structure with synthetic substitutes.

However, along with the innumerable benefits provided by nanaotechnology, safety concerns have also been raised.

Nanoparticles have a large surface area volume ratio. Greater the specific surface area, more are the chances it could lead to increased rate of absorption through the skin, lungs or digestive tract. This could cause undesirable effects in the lungs and other organs throughout the body, as non-degradable nanoparticles could accumulate. The primary toxic effect is to induce inflammation in the respiratory tract, causing tissue damage and subsequent systemic effects. Transport through the blood stream to other vital organs or tissues throughout the body may result into cardiovascular and other extra pulmonary effects. Penetration via skin might facilitate the production of reactive molecules that could lead to cell damage [57].

Therefore, conflicting views remain regarding the use of nanodentistry in vivo. The field of Nanodentistry is still developing and many issues are still to be resolved. Future research needs to address these before nanotechnology can be incorporated into the armamentarium of modern dentistry.

In India, nanodentistry remains far away from reality. Undoubtedly, though it has been a topic of great interest in recent years, not much progress has taken place to avail its benefits. Problems for research in nanotechnology in India can be summarized as:

- Painfully slow strategic decisions
- Sub-optimal funding
- Lack of engagement of private enterprises
- Problem of retention of trained manpower [58]

Stem Cells

Stem cells are immature, unspecialized cells that have the potential to develop into many different cell lineages via differentiation [59]. Given their unique abilities, stem cells are particularly important for developing innovative technologies for tissue engineering strategies to regenerate or replace damaged, diseased or missing tissues. The focus of stem cell research in dentistry is the regeneration of missing oral tissues which is a major concern to prosthodontists. Therefore, stem-cell-based regenerative technology is considered to represent a new frontier in prosthodontic medicine [60].

It is now known that stem cells can be collected from the dental pulp of both deciduous and permanent teeth, periodontal ligament, apical papilla, and dental follicle. Indeed, current moves towards isolation, collection, and cryopreservation of dental pulp progenitor cells for "dental stem cell banking" are now feasible and commercially possible. Considering the status of stem cell therapy in India, stem cell banking has successfully been introduced in various parts of the country (around 15 cities). Dental stem cells/ mesenchymal stem cells are harvested from the milk teeth of children in the age group of 6–12 years. Stem cell therapy is the new realm of regenerative medicine for Diabetes Type 1, wound healing, Parkinson's, spinal Cord Injury, myocardial infarction, osteoarthritis and for many more ailments.

This clearly shows that we have an opportunity to advance restorative dentistry into a new era, harnessing the biological activity of the dental tissues to facilitate wound healing and tissue regeneration [61]. Apart from this, they are now being tested for their potential use in a variety of clinical applications, ranging from use as immuno-modulatory agents to use as regenerative stem cells that can facilitate regeneration of cardiac tissues, bone, and even neuronal tissues. Human mesenchymal stem cells, including dental stem cells, have been tested for spinal cord regeneration in animal models. Although, only a few dental stem cell therapies have been conducted in humans, but the vast majority of these studies being performed in animal models, will pave the way for their increased utilization in humans in the future.

In the near future, stem cell and tissue engineering therapies are expected to provide a novel capability to regenerate large defects in periodontal tissues and alveolar bone, and ultimately replace the lost tooth itself. Although the concept of engineering a whole tooth offers exciting potential and has been shown to be potentially feasible in controlled in vivo animal models [62–64], significant clinical challenges remain. Regeneration of the entire tooth is expected to be one of the biggest achievements in the field of dentistry and science.

Conclusion

In recent years, the field of restorative dentistry has embossed its presence by taking major leaps in research and further bringing it into practice. Over the next decade, as prices come down and the dentists become more comfortable with the new technologies, we can expect to see more of digital dentistry. Using digital technologies in the dental practice will enable better and faster diagnosis, patient education and communication. Same-day restorations will become more popular and will likely expand to fixed, partial and complete removable dentures. Furthermore, the dental community will experience a revolution when subtractive manufacturing will be substituted by additive manufacturing techniques leading to less wastage, mass production of high quality dental prostheses etc. Likewise, the digital world will continue to evolve with new and improved tools and with the ultimate goal of benefiting the patients we treat. Nevertheless, along with the rapid advancements, there is a need to transform and to

keep abreast with the newer technological advancements in this field. The initial discomforts of transition should not stand in the way of progression. If the technology exists that allows us to improve patient care, then as professionals we should be eager to embrace it.

Dental science, as it stands today looks into implants with a great degree of hope for the future. Implant prosthodontics will continue to increase in need and demand, become more refined clinically, and become more and more a routine part of prosthodontic practices. However, looking at the long term perspective, it might be speculated that the interest in dental implants may abate as increased knowledge of human genetics and tissue engineering open the possibility of in vivo growth of teeth, perhaps making implants obsolete.

Lastly, the future of prosthodontics resides nowhere else but, in two areas, that is—in our minds and in our hands. Technology and science will help us in being the new age prosthodontists of tomorrow. In the upcoming years, one can envisage remote sensing robotic devices treating the patients under the commands of the master—the dentist, even without his immediate presence. In all, considering the above advancements, dentistry has a high potential to serve the patients better than ever before.

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