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REVIEW ARTICLE

Digitization and Its Futuristic Approach in Prosthodontics

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Abstract Digitization has become part and parcel of the contemporary prosthodontics with the probability of most of the procedures being based on the digital techniques in near future. Let us think of X-rays or photographs, making impressions, recording jaw movements or fabricating prosthesis, educating and training new dentists or patient motivation for practice build up, all has become digital. CAD-CAM has revolutionized not just the ceramic technology but has also been used for the CAD-CAM implant surgeries, maxillofacial prosthesis and diagnostic splints. Today a practicing dentist needs to be abreast with the latest but with the technology changing so fast, this poses a great challenge. There is endless scope of digitisation and technology in prosthodontics- let it be in the clinical and lab procedures like use of CAD-CAM technology, stereolithography, rapid prototyping, use of virtual articulators and digital face bows, digital radiographs, or in the field of training, education and research by the use of virtual patient programs, dental softwares, optoelectronic recording of jaw motion, digital instron machine, retention testing device, audiovisual aids,… the list will remain endless. The article reviews those various aspects of prosthodontics where digitization has modified the conventional procedures. For discussion they have been considered under the educational aspect, diagnostics, treatment procedures, prosthesis fabrication and lastly the research and futuristic development. The day is not far when remote sensing robotic devices would be performing the restorations under the command and surveillance of the master—the dentist without his immediate presence.

Keywords Digitisation · Digital technology · Virtual dentistry · Recent/contemporary prosthodontics

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Introduction

Background

Dentistry can be dated back to eighteenth century, when impressions meant use of waxes and plaster of Paris [66]; and the dental equipment consisted of hand driven and later water driven motors. From then there's been a long journey to achieve the contemporary paraphernalia [22, 26, 72]. Along with limited materials and equipment there were selective treatment options but, with the passing years and the endless growth in research, emerged a gamut of options in dentistry. The contemporary dental practice has endless options for preserving oral health and provides next to natural aesthetics with an enhanced approach, reduced treatment time, minimized error potential and better quality assurance. These reasons rightly explain present day dentistry being called the Golden Age of Dentistry [75]. Evolution of CAD-CAM ceramics could make single sitting restorative dentistry a reality in the 21st Century [33]. This has been possible by the visionary approach of great researchers, scientists and practitioners.

Digitization started to influence dental fraternity with the form of audio-visual aids in both teaching and patient education. It was in 1980s that advances in computerisation, optics, miniaturisation and laser technologies enabled capture of dental impressions [66]. Even digital radiography was used widely in medicine, but it was only in the 1980s, that the first intra-oral sensors were developed for use in dentistry. The early systems could not capture panoramic and cephalometric images, and this made it impossible for surgeries to abandon film processing and adopt digital technology [51]. The development of cost-effective intra- and extra-oral digital technology coupled with an increase in computerization of practices has made digital imaging a superior alternative in many respects to conventional film imaging. Early 1980s also paved the way for computer-aided design/computer-aided manufacturing (CAD/CAM) technology. CAD-CAM initially was used for enabling design in aircraft and automotive industries; it was first patented in dentistry by Dr. Duret (1984). Since then, the technology has evolved in two directions—the intraoperatory application for single appointment restoration (using prefabricated ceramic monoblocks) and paralleled by, CAD/CAM systems for commercial production centres and dental laboratories [34, 43, 50, 66].

The research and development in material science and the related paraphernalia cater to preservation of oral structures with an early diagnosis, repair of dental disease to achieve aesthetics and function with high level of predictability and even less number of sittings. Digital technology has immense influence over the clinical aspect, laboratory procedures, training of students, patient motivation, practice management and not the least dental research. Today a dentist has ample of options to choose from but needs to be abreast with the developing technology to avail them all. With the mounting research it is quite challenging to keep pace with it but is the need of the hour. More updated the knowledge, better we provide to our patients and hence helping towards the upliftment of dental fraternity.

Need of Review

Digitisation, being so significant in the dental practice needs to be understood well. There are a few systematic reviews found regarding the effect of fast growing digital technology in prosthodontics. The array of developments need to be known, as they either affect the contemporary practice or may have a significant futuristic outcome, and hence give an endless scope on revision. Such reviews would help the dental fraternity to be refreshed with the latest, and cultivate a futuristic vision.

Objective

Review has been written with a contemporary reference considering the pros and cons of various technological progresses. The impact of digital technology in prosthodontics is immense, hence for ease its influence has been considered under sections—the clinical aspect, laboratory procedures, training of students, patient motivation, practice management and not the least dental research. It tends to be a narration of influences of digitisation on prothodontic practice, teaching and research. With technology evolving so fast dentist needs to be abreast with these developments.

Methods

Search Strategy

Electronic search was conducted for online journals to search for relevant articles and material with selected keywords like digitisation in dentistry, digital technology, CAD-CAM, virtual technology, recent developments, digital radiographs, contemporary practice etc. The various sites scanned were—MEDLINE/Pubmed journals and Cochrane reviews. Handsearching was done for articles in the following journals—Journal of Prosthetic dentistry, Dental clinics of North America, Journal of American dental association, Journal of Indian Prosthodontic society, Journal of Prosthodontics, Journal of contemporary dental practice, Journal dental research and Dental Practice.

Bibliographies of the selected articles were referred for relevant papers. Grey literature was included from journals and online publications, World Wide Web, online conference proceedings and reports etc. All search included relevant articles uptill 2012.

Selection Criteria

The authors independently assessed the relevant papers for inclusion; any disagreements were resolved by discussion. Selection included literature suggesting use of digital techniques in areas of dentistry like clinical, laboratory steps, training, patient motivation or research. Articles with pros and cons of various techniques and futuristic opinion regarding them were preferred.

Data Collection and Analysis

A comprehensive search for the relevant studies was carried on health related electronic bibliographic databases, a narrative synthesis was conducted. Articles were searched and screened according to the inclusion criteria.

Results

The literature regarding recent techniques helps us assimilate latest trends for benefit of patient and expansion of dental profession as a whole. The transition from old to new occurs with basic aim of making patients life better, and also providing a convenient practice for dentists. To achieve the above it is needed to explore all options, it's with use and time that the drawbacks and limitations of newer materials and methods would surface. To utilise technology in its best form it needs to be gripped well. Digitisation is quite an immense subject and current review has further scope of elaboration in each of its aspects.

AID in Clinical Practice

Digital technology has impact over the patient motivation, practice management and clinical treatment procedures. Be it digital radiographs aiding in diagnosis, CAD-CAM ceramics for better aesthetics and function with less number of appointments, rapid prototyping and stereolithography for maxillofacial prosthesis fabrication and still others provide high level of predictability, more convenience and even less number of sittings.

AID to Research

Research has to be kept on for better dental productivity. Be it development of material science, or the latest equipment or enhanced treatment techniques…all owe to continued research. Old methods undoubtedly form the basis of research science but have been enhanced upon by digital methods. One being, the incorporation of digitisation in the Finite element analysis (FEA) by use of computerised or software based models. FEA is based on force and displacement relationships for analysis and design of large and complex structures. It incorporates a computer model of a material or design that can be stressed and endured to differing amount and direction of force and the effect analyzed. This has found place in research to analyze the stresses transferred by various materials, their mechanical properties, effect of different designs on dentofacial structures, implant loading and their placement and other endless options [15, 53, 55, 69].

Web based surveys based been retrospective studies provide an enormous subject research method over a global platform [52, 61]. Other areas where digitisation has helped in research is use of digital instron machine for material testing, retention testing devices, use of softwares for anthropometric, cephalometric and esthetical ratio studies.

Discussion

Digitization has captured the world with its ubiquitous applications, such that no field remains aloof. If casually said, anything and everything is just a click away…. The future of dental practice is closely linked to the utilization of computer-based technology and virtual reality, which allows the dental surgeon to simulate true life situations in patients [21, 23, 25, 26, 41]. The term 'Digitisation' refers to conversion of an image or signal into digital code by scanning, tracing, or a graphics tablet or using an analogue to digital conversion device. It is a process of making a digital copy or recording of something that was originally analogue; which might be a document, artefact, sound, performance or natural phenomena. There is endless scope of digitisation and technology in prosthodontics—starting from motivating a patient and maintaining records to making digital impressions, use of digital radiographs and photographs, use of virtual articulators and digital face bows for planning and fabrication of prosthesis; or for processing of restorations with use of CADCAM technology, stereolithography, rapid prototyping etc. The applications of above are becoming essential in field of training, education and research akin to clinical practice. Research has been enhanced by utilising virtual patient programs, dental softwares; digital recording of jaw motion, FEA and digital instron machine etc.… the list will remain endless. This review has been an attempt to elaborate some of the significant points of above. This technological influence over the dental service if used wisely would make practice more convenient for both dentist and the patient.

Role of Digitization for Patient Motivation and Practice Management

Building a good rapport with the patient and educating him/her regarding their poor oral health and need for professional help, can be assisted using intraoral camera, education softwares, videos, 2D and 3D images of dental procedures. This helps them understand the interrelationship of teeth with general health, and also wade away dental fear. Softwares like XCPT, Dentrix and Bite FX can be used for a better understanding of treatment plans portrayed in a visually convincing way [8, 21, 38]. Such softwares digitize analogue radiographs or capture any digital radiograph (panoramic, periapical or CT scan) and give the dentist the ability to annotate the image and to place a variety of objects, crowns, implants, abutments and bone grafts to explain to the patient exactly what the doctor sees. They can be well termed as an on-the-spot consultation tool, to build trust and save time because the patient immediately grasps the ideas being presented. Similar softwares have been in use in orthodontics to design the treatment plan on a computer and generate 3D virtual treatment course to represent teeth movements to an ideal position (Invisalign-ClinCheck™ software). Hence the treatment results can be visualized in a three dimensional form and help motivate a patient better [64].

Literature suggests use of internet based programs for educating patients about tobacco cessation. Basis of such interventions are the estimated figures of 1.73 billion internet users worldwide and expected to increase further. These internet based interventions were found to be highly cost effective with an easy access from home, public libraries and other internet points. But mixed results were found, not consistent depending on effect of face to face interaction on patient psychology [14].

The computerized data base technology has decreased the problem of limited storage space for patient records as even the plaster casts can be converted to virtual 3D study models. Conferencing and communication amongst the functioning team has become easier with the newer communication methods.

Role of Digitization for Training and Research

The education and training of dental students has also become more effectual and practical with audiovisual aids, which aid for better presentation of the subject. Learning through the World Wide Web, and visualizing many dental related videos on You-tube is just a click away for today's generation. One big leap in field of education is with virtual softwares like Virtual dental patient (CANDIDE™, PERIOSLIM™) that allow learning with the true feel of working on a patient. Surgical training has traditionally been one of apprenticeship, where the surgical trainee learns to perform surgery under the supervision of a trained surgeon. This is time consuming costly, and of variable effectiveness. Training using a virtual reality simulator is an option to supplement standard training and assessing the competency of a surgeon in an ethical way [27, 29, 46]. These systems have been applied in the medical fraternity for learning laparoscopic procedures, diathermy and other surgeries; use of virtual drilling systems would similarly aid dental students in getting acquainted with tooth anatomy, handling of drilling instruments and other challenges associated with drilling procedure. This can prove to be beneficial for teaching restorative procedures, tooth preparation, sutures, implant related surgeries and others, with the feel of working on a patient without harm or any risk to patient [62, 73] Others have also expressed this to be inferior to traditional methods of teaching due to lack of patient interaction [27]. The other quite a significant use of virtual technology is use of virtual articulators discussed later.

Research forms backbone for development of dentistry as a professional science. Computers and various softwares have been an aid in studies. Scores of web based studies and surveys have been listed in literature [52, 61]. These have been retrospective studies or opinion based researches and provide enhanced subject research methods on a global platform. These surveys were found to be 38 % less on cost compared to traditional mail surveys [54]. Softwares like Coral draw and Adobe Photoshop allow evaluation of photographs for anthropometric and tooth ratios [20, 64]. Laser digitisation of casts was done using 3D optical digitising technology and evaluated for accuracy to see the effect of tray selection and cast formation technique. The method hence paved way for accurate techniques of cast's measurements as an alternative to manual measurements [5]. Digital machines have also been an aid in measuring certain parameters which are otherwise difficult to analyse quantitatively. This has been done with an aim of increasing reliability and validity of research example use of a digital device to check retention of lower dentures. Same can be applied to direct retainers etc. [2].

Material testing has become more efficient with better testing methods like digital Instron machine. INSTRON is a contraction of the words "instrument" and "electronics" and represented an important milestone in the materials' testing machine, since 1946 when its use was established in Canton. Rockwell tester was marketed over 80 years ago and later developments involved micro-indentation testers, Knoop and Vickers testing, Brale diamond indenter, Brinell portable tester etc. many of which found use in dental research. Shore Instruments, developed durometer which could be used for measuring the hardness of plastics, rubbers and elastomers. From pencil style and analogue durometer, manual operating stands and rubber test blocks, today they have revolutionised to S1 digital durometer with interchangeable probes. Similarly there has been development in impact testing machines; all these improved testing machines hence allow a better and accurate understanding of material properties.

Finite element analysis is based on force and displacement relationships for analysis and design of large and complex structures. It incorporates a computer model of a material or design that can be stressed and endured to differing amount and direction of force and the effect analyzed. This has found place in research to analyze the stresses transferred by various materials, their mechanical properties, effect of different designs on dentofacial structures, implant loading and their placement and other endless options [15, 53, 56, 69].

Role of Digitization in Diagnosis and Treatment Planning

A good treatment begins with the right diagnosis, and the dental X rays have been an important diagnostic aid from the start. Investigators have stated digitized radiography to be superior to the traditional radiograph in disclosing the defects affecting hard tooth tissue (dental caries) [31, 51]. The computerized digital sensitivity allows for the use of up to 1024 gray levels, thus it enables the operator to distinguish the earliest changes that could affect the hard tissues especially in areas of low contrast e.g. detection of incipient caries at the inter-proximal areas. *Digital radiography* offers immediate viewing of images which is highly desirable during implant procedures, post placement and patient education. It omits the use and maintenance of chemicals and dark rooms. Images can be enhanced using the intuitive software for easier reading and diagnosis, comparison and subsequent viewing. The storage and electronic distribution of digital images allows better communication with other practitioners and third-party benefit companies and not to forget the decreased radiation exposure by fewer retakes (no processing errors). 3D radiographs have been called the fourth dimension of endodontic treatment planning as they improve the preoperative visibility of lateral canals, presence/absence of additional canals and knowing all possible about the given tooth anatomy before any invasive procedure [3, 6, 9, 44].

On the other hand, software related barriers need to be overcome for use of computers in dental radiography; the alteration of an image to remove artefacts or scratches needs to be documented and cannot be relied on as an evidence in the legal sense [49]. Its high cost also does not encourage many of the practitioners; however, some newly introduced equipment with a reasonable price have aided in a transition from traditional to computerized radiography.

Radiovisiography (RVG) is a multi-component system advocated by Dr Francis Mouyen in 1989 [47], which enables the operator to capture colored images from the patient mouth via an intra—oral camera and the transfer of this image to the computer. The images on a computer can be zoomed, rotated, cut or edited; or further manipulated-enhancement, contrast stretching and reversing. The newer versions of intra-oral cameras are very light in weight (less than 50 g) and the illumination for image capture is no longer a fibre-optic which is affected by aging but it became light emitting diodes which give adequate white illumination to comply with darkness inside the mouth. Radiation exposure is reduced with RVG when compared to conventional radiography; a Cone beam CT further helps in reduction of radiation exposure by nearly 10 to 30 times less than that of a conventional CT radiograph.

Advent of digital radiography has enhanced the study of temperomandibular joint- its functioning, pathophysiology and disorders. Other than the conventional plain film modalities, array of contemporary options available for TMJ imaging are—CT with cone-beam technology, MRI and nuclear imaging including single-photon emission computed tomography and positron emission tomography. These advancements improve the understanding of this complex joint and its pathology, ultimately leading to improved treatment outcomes. Refinement in magnetic resonance technology like (1) use of new alloys for lighter weight permanent magnets with reduced operating costs; (2) gradient coil technology for more rapid image acquisition leading to the possibility of true cine magnetic resonance; and (3) smaller, more powerful computers for more rapid data processing have implications over anatomic and physiologic assessments of the joint along with reduced costs [28, 30, 39].

Diagnostic imaging is an essential component of implant treatment planning, and a variety of advanced imaging modalities have been recommended to assist the dentist in assessing potential sites for implants. Developments in cross-sectional imaging techniques such as spiral tomography and reformatted computerized tomograms have become increasingly popular in the preoperative assessment and planning for dental implant. Radiographs are used to evaluate bone quantity, quality, density and aesthetic site assessment for implant placement. Digital panoramic imaging being one of the earliest and most sought after, as it is a non-invasive procedure. Authors suggest considering risk–benefit analysis before applying newer imaging methods e.g. radiation exposure etc. which also makes the latter most used [18, 58].

Dental photography has always been an aid for patient education and aesthetic treatment planning. Intuitive softwares make it possible to visualise post treatment effect, variation of tooth size and form etc. It is utilised for many web based studies to survey opinions of dentists and non dentist population [52, 61]. Photographic records are easier to store, can be viewed at various angulations and easily measured. Regular photographic records, at all dental visits could be great help to examine the age changes like occlusal vertical dimension, tooth colour and facial changes. This can redefine practice of prosthodontics with their ability of visual communication and medicolegal documentation for contemporary practice. Use of digital photographs has also been explored in areas of maxillofacial restoration to replicate the iris for fabricating a custom ocular prosthesis for an anopthalmic patient and restoring other maxillofacial defects like mandibulectomy [1, 8]. Softwares like Adobe Photoshop and Coral Draw allow potential for the digital subtraction photography, which improves detection of caries, periapical lesions, bone changes, periapical healing following an endodontic treatment as early as 2 months [7].

Diagnosing and treating occlusal errors has never been easy. To analyze the problems arising from occlusal origin constitute a great difficulty due to the complex nature of the human occlusal system. An atraumatic dental occlusion is the area of growing demand in the fields of restorative and reconstructive dentistry [40, 59]. Systems like Tekscan (T scan) and Matscan permit a precise study of occlusal contacts and the forces created; examining even slightest of occlusal interferences, significant in full mouth rehabilitation and implant protected occlusion (IPO). It was in 1988, Dr William Maness [42] working in Tufts introduced his automated computerized sensor for analysis of the dental occlusion. Aim was to register the patient occlusion on a thin patented 60 microns thickness disposable sensor to record instantaneously the patient bite in terms of location, timing and force of every tooth in contact. This record is transferred to a computing system which can make an actual simulation of the patient occlusion on a monitor, assuming the different situations possible during centric, eccentric and functional movements. This provides both qualitative and quantitative assessment of occlusion. The system was termed T scan, and got accepted well due to its advantages like simple operation, dynamic viewing of occlusion, timed analysis of force during various positions of teeth contact and the possibility of permanent documentation and monitoring of the occlusal condition after carrying on the various treatment protocols. It not only presented a valuable method for clinical evaluation and understanding of the occlusal problems but also an important tool for teaching purposes. There have been many improvements in the system (up to 4th generation) now allowing use of a 100 microns thin sensor and software to analyze and display the timing and force of the patients bite in 2D and 3D graphics.

Akin to occlusion knowing details of mandibular motion and TMJ also pose a challenge. Their detailed observation may form a basis for diagnosing musculoskeletal disorders of the jaws, to monitor progress or evaluate prosthodontic treatment functional results. Various electronic, telemetric methods, magnetometry and optoelectronic methods aid in above. Mandibular kinematics permits detection and assessment of TMJ functional irregularities due to internal obstacles such as a displaced articular disc. Jaw tracking devices (K6 Diagnostics) would be helpful in studying jaw movements and hence occlusion which may be a microtrauma for temporomandibular disorder [36, 45]. The elevated muscle activity associated with malocclusion directed nocioception can be detected with surface electromyography (EMG). An EMG device named BITE STRIP™ can record muscle activity for 6 h which provides useful information in nocturnal bruxism. All these techniques mainly revolve around the aim of studying stomatognathic system, as accurately and precisely possible. Computerized pantographs like Cyberhoby articulator can be used for restoration of deteriorated dentitions, thereby relating the stomatognathic system near to accurate.

Role of Digitisation in Treatment and Associated Laboratory AID

Impression making is an indispensible part of prosthodontics, and digital impressions have revolutionised this task. These omit the use of materials and their related inaccuracies; this historical development of impressions has been aptly called Bites to Bytes [66] Digital recording allows multiple uses without loss of accuracy; omit need of disinfection and could be beneficial in patients with hypersensitive palate. Advent of digital impressions has aided in further shortening the chairside time for CAD – CAM restorations [10–12].

But as with any other digital technology, the technique sensitivity increases; inadequate tooth preparation or insufficient soft-tissue management cannot be compensated for. Sufficient gingival displacement is required for good emergence profile, or egression silhouette as scanning through gingival tissue is not possible. 3D optical digitising technology allows 3D images to be scanned with a 3D scanner and these can be coupled with computerised milling machines for processing restorations. The scanning method differs in various systems, regarding the distance to be kept from tooth; kind of light used or need of powdering the surface to be scanned. The E4D scanner has a separate scanning and milling unit with automated interunit communication, its scanner utilises a red light laser (20,000 cycles per second) to create a 3D model. The ICEverything™ (ICE) feature of the system's Dentalogic™ software takes pictures of teeth and gingiva before and after tooth preparation with occlusal registration. The 3D ICE view makes margin detection easier. CEREC AC gives dentists the choice of implementing in office fabrication or sending the digital images with CEREC CONNECT directly to the laboratory, where the restoration can either be milled directly or a model can be created for traditional fabrication of the restoration. Its scanner operates using visible blue light (LEDs) with shorter wavelengths than previous CEREC models, hence increasing the accuracy of the scan. Image acquisition is more rapid with CEREC AC than with previous models due to the continuous capturing of a series of images by the scanner once in position. The system software has been designed to verify the digital preparation and interocclusal clearance followed by which a digital version of the proposed restoration is created prior to its fabrication. The CEREC MC XL milling centre can be used to create full contour crowns in six minutes. Other systems used for chairside digital impression is Lava C·O.S., iTero scanner; the latter utilizes parallel confocal imaging to capture a 3D digital impression of the tooth surface, contours and gingival structure. Parallel light emission from the scanner, does not need to be held a set distance from the tooth and will also scan when touching the teeth, enables the detection of angled contours. As mentioned another difference between the various systems is the requirement for powdering. The CEREC system requires a coating of reflective powder on the dry preparation prior to scanning. Light powdering is required when using the Lava C.O.S. system. The iTero system does not require powdering. The optical impressions and other digital records can be much needed information for the functioning of forensic dentistry [33, 34, 57] Digital impressions with LAVA^{TM} Oral Chairside Scanner have been used for assessment of gingival contour and compared with traditional clinical indices like modified gingival index and bleeding index [48].

Another area of digital application has been shade replication, and this has always been prone for inter and intra operator variability. Visual shade matching is now being overrun with methods like photography, colorimeters and spectrophotometers (Shade Match, Shade Vision, Shade Eye and Clear Match) which give more consistent shade and a near life effect with colour mapping of tooth selected. Digital imaging and shade matching decrease the inter-operator and intra-operator variability; and also eases the communication with the laboratory [4, 32].

The accuracy and precision in planning and early diagnosis also allows use of approaches like microrotary instrumentation, air abrasion and laser technology with bonded resin based composite restorations [19].

Along with clinical procedures even the production stages have become automated; with the cutting edge technology of CAD-CAM or conoscopic system (Straumann, LAVA, CEREC-CAD-CAM scanners, software and ceramic material). CAD/CAM systems have three functional components: data capture unit or scanner, CAD to design the restoration and CAM to fabricate the restoration. The precision scanning technique, intuitive design software and industrial manufacturing machines decrease the laboratory deficiencies of the restoration and has made possible the use of zirconium based ceramics (which otherwise is difficult to machine), hence resulting in excellent high quality metal free dental prosthesis. CAD was initially based on "subtractive method", but the recent processes involve "additive" approaches like rapid prototyping and selective laser sintering technologies or a combination of additive and subtractive CAM [33, 37, 50]. The latter decreases material wastage. It not just finds place in area of ceramic veneers, crowns, inlays, onlays but also posts, occlusal splints or surgical splints for implant planning, and even in fabrication of maxillofacial prosthesis [13, 16]. CAD-CAM aided implant surgeries aid in proper planning and execution of treatment and result in biomechanically sound prosthesis, implementing minimally invasive flapless procedure [13, 63]. Tactile registration based Implant locating System has been proposed to be simple method for accurate implant design and placement, requiring only basic computer experience, minimal operational space, and low infrastructure investment [60]. Computer-assisted surgery help to improve oral implant planning and the intraoral bone-sounding device maps the surface of the jaw through the soft tissue. Bone contour data are registered over the computerized tomographic image. Guided by treatment preplanning software, a chairside robotic manipulator fabricates guiding sleeves that direct the drill and implant during the osteotomy and implant placement, respectively [63, 64]. Construction of CAD/CAM bilateral ear prostheses has been described using laser scanning of the defective regions of a patient's face and rapid prototyping using 3D anatomic models from digital ear library.

The accuracy of the photographic 3D imaging system has been found accurate for clinical description of the midface structures and may be potentially useful for rapid prototyping of facial prostheses [35].

Advances in computer technology enable cost effective production of individual pieces. Further research is needed to utilize this technology for veneering, which would not just decrease manual error but also processing time. The CAM component is expected to undergo a remarkable change towards adaptation of high speed machining to permit faster removal of material. This would reduce machining time and could reduce the production costs.

Another important technological application is use of virtual articulators. Treating occlusion and restoring oral health needs a good articulator simulating the oral environment, there has been immense development in design of articulators so as they can closely simulate the mouth, Bernard Frank said "Mouth is the best articulator" considering limitations of the existing articulators. Application of virtual technology to articulator design aims to reproduce close to real life situation; the virtual articulator has been designed for the exhaustive analysis of static and dynamic occlusion, with the purpose of substituting mechanical articulators and avoiding their errors. It can simulate the specific masticatory movement of the patient, and the program calculates the sites where the opposing teeth come into contact during mandibular animation. Mechanical articulators are different from the real life biological setting; they cannot simulate masticatory movements that are dependent upon the muscle patterns and resilience of the soft tissues and joint disc. Moreover, tooth mobility cannot be simulated by plaster models; as a result, the latter are unable to reproduce the real life dynamic conditions of occlusion. And a passing mention to other limitations derived from the procedures and materials used for assembling the models in the articulator: precision in orienting the model, expansion and contraction of the plaster, deformation of the bite registration material, the stability of the articulator, etc. [24, 41]. Use of virtual technology has been mentioned as used for studying occlusion on mounted patients casts [17].

To analyse a situation on virtual articulator the plaster models need to be scanned with a scanner, CT scan or 3D imaging over which prosthesis is then statically modelled and later the excursive movements are simulated using a CAD system (or ultrasound or optoelectronic methods) analyzing occlusal collisions to adequate/modify the design. The basic system of the virtual articulator generates an animation of the movements of the mandible based on the input data, and calculates the points of occlusion, which in turn are shown on-screen by means of some type of code. Digitised dental arches have been studied using virtual articulator of Kordass and Gaertner, Szentpétery's virtual dental articulator and needs more research; a digital face-bow is another aspect of this project which allows for a more precise location of the occlusal surface.

Future Scope of Digitisation

The pace at which Digitization is conquering dental practice will revolutionise the future of dentistry. Research in areas like Optical coherence tomography (D4D Technologies) and would allow creating a sliced image of the tooth or other structures. It could be used for potential caries diagnosis, tooth crack location, CAD/CAM imaging, subgingival margin location, periodontal diagnosis, soft tissue analysis, and more. Presently digital impressions are extremely sensitive to face movements which make it difficult to scan preparations intaorally. The newer developments are expected to give more consistent results. The Evolution 4D system, currently under development by D4D Technologies (Richardson, Texas), is expected to have intraoral data capture capabilities. Other commercially available CAD/CAM systems capture data from models, using mechanical or optical digitizers of various types. With few exceptions, these high-precision digitizers use technologies that prevent them from being used intraorally. The complete edentulous arches if recorded digitally can be treated without the discrepancy of REALEFF factor. Other areas to be explored include use of virtual articulators and digital face bows to facilitate automatic design of the occlusal surface.

Authors' Conclusion

Advances in digital imaging, computer aided design, internet communication, digital manufacturing and new materials have undoubtedly simplified the diagnostic process and improved treatment outcomes. Patient care and communication can be enhanced substantially by using several new technologies.

Implications on Clinical Practice

Digital technology has impact over the patient motivation, practice management and clinical treatment procedures. Be it digital radiographs aiding in diagnosis, CAD-CAM ceramics for better aesthetics and function with less number of appointments, rapid prototyping and stereolithography for maxillofacial prosthesis fabrication and still others provide high level of predictability, more convenience and even less number of sittings.

Implications on Research

Research has to be kept on for better dental productivity. Be it development of material science, or the latest equipment or enhanced treatment techniques…all owe to continued research. Digitisation permits many newer and effective methods of research.

But the major hindrance in acceptance of the recent technology is the associated costs. Dedicated and timeless research continues to develop hardware and software so as to make these technologies in reach of the practitioners. Also the training and continued education is needed to adapt to newer technology. If used well, this would not just redefine the way dentistry is practiced but help to provide better treatment results, and achieve the utmost for the profession.

There is much scope of detailed discussion on every aspect of this review, and to be applied in contemporary practice there's a need that the practitioner stays abreast with the latest. And to end with a note, that the endeavour is to take *Prosthodontics to greater heights*.

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