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Chapter

Clinical Computing in Dentistry

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Abstract

Machines can seldom replace dentists in rightly handling the patients with optimistic human insight, considerations, creative planning and the monitoring of psychological acceptance and comfort experienced by any patient with the rehabilitation done. Intelligent computer related armamentarium with software can still help dental practitioners detect typical medical and dental signs and classify them according to certain rules more effectively. Based on image analysis algorithms, CAD systems can be used to look for signs of any tooth pathology that can be spotted in dental X-ray or cone beam computed tomography (CBCT) images. Applying computer vision algorithms to high-resolution CBCT slices helps to a great extent in diagnosing periapical lesions like granulomas, cysts, etc., and can help creating 3-D model of a root canal that reflects its shape with sufficient precision facilitating an optimum endodontic treatment planning. Hence, computer vision systems are already able to speed up the diagnostic process and provide a valuable second opinion in doubtful cases. This can lead a dentist and the patient thoroughly experience an optimistic acceptance and satisfaction of the treatment done.

Keywords: software, CBCT, clinical computing, computer vision

1. Introduction

The inevitable significance of virtual reality in the practice of dentistry is a result of continuous adherence of public practice with computer based technologies. Research work in the recent decades quoted many innovative and technological advancements introduced in the field of dentistry. Computer technology seems to form the future of dentistry [14]. Today's dental practice shows an evident usage of CAD-CAM of dental appliances and prostheses worldwide. Yet, VR (virtual reality) and AR (augmented reality) techniques are tracking their own significance in learning and working and are still not explored sufficiently. Virtual reality (VR) technologies have a strong impact on research, development, and industrial production.

VR technologies in dentistry will be used to provide better education and training by simulating complex contexts and enhancing procedures that are traditionally limited, such as work with mechanical articulator.

This chapter aims at discussing the computer based technologies including VR and AR simulators, CAD-CAM systems and their multidimensional application in dentistry.

2. Virtual reality technology

In today's reality, current trends of technologies are at optimum acceleration in a wide range. Virtual reality technology is defined as a method by which an environment is three dimensionally simulated or replicated, giving the user a sense of being inside it, controlling it and personally interacting with it [3, 4]. Designing of a new product brings in the significance and wide usage of VR and the incorporation of 3D modelling in it [1]. The field of health care can never be an exception in the usage of VR as its usage is remarkable in the instructions of surgical procedures [14, 36, 39], student training and patient [31, 41] instructions. VR technology has evidences in successful treatment of complex regional pain syndromes [15] and in creating virtual environment [6] to assess behaviour and rehabilitate cognitive and functional abilities in patients with psychological disorders to help in their treatment [17].

3. Features of virtual reality

Two basic features of virtual reality are: (i) immersion and (ii) interaction.

3.1 Immersion

Immersion is the sense of being present in virtual environment. 3D images, sound and other stimuli are created to simulate an environment that surrounds the user and make them feel a physical presence in a non-physical (non-real) world [22, 32]. Depending on the capabilities of various VR systems ranging from fully immersive to non-immersive systems, the degree of user's belief of being present is noted [11].

3.2 Interaction

Interaction is the power of user to modify the virtual environment [32]. This is well understood with a difference felt between 3D movies and virtual environments. VR systems readily facilitates user to interact with the virtual world, move around, see from various angles, reach, touch and reshape it evidently. Head mounted video goggles wired clothing and fibre optic data gloves can help this sort of interaction possibly [33].

4. Types of VR systems

Virtual reality systems are classified into three major groups such as non-immersive, semi-immersive and immersive based on immersion and type of components used in the system [11] (**Figure 1**).

4.1 Immersive VR simulation

Possibility of giving the user the psycho-physical experience of being surrounded completely by virtual computer generated environment (as illustrated in **Figure 2**) is brought by immersive VR simulation using hardware, software and interaction devices. Stereoscopy is a process by which full immersion, i.e., the highest level of immersion is produced by head mounted device that displays 3D images. This process shows two images to user—one per eye—which are combined by brain into single 3D image. Data gloves are other components that enable the person to interact with objects. Pulling the objects, twisting or gripping are best examples and these components may also give

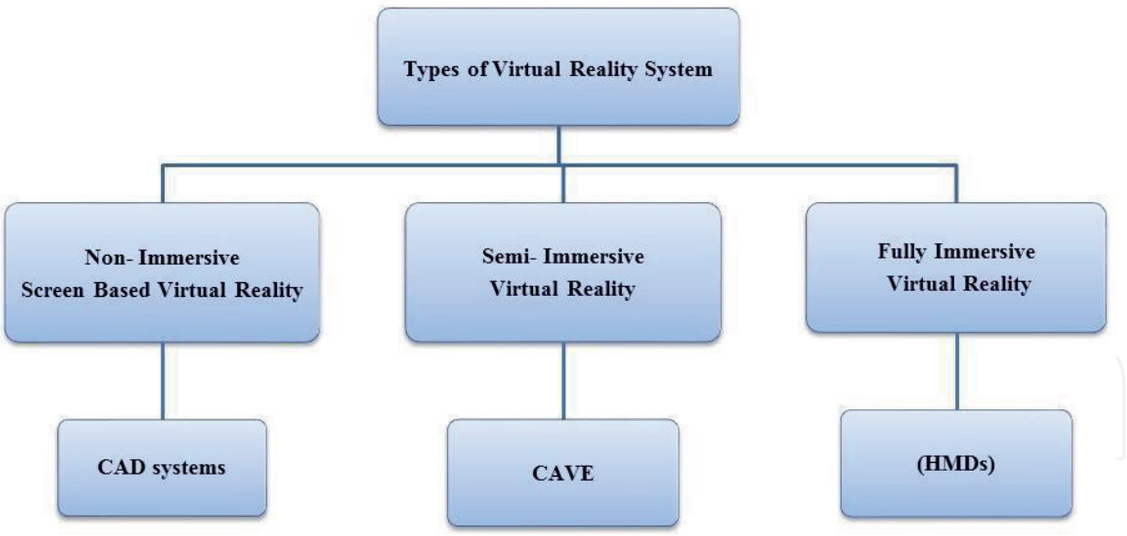

Figure 1.
Types of virtual reality systems [5].

Figure 2.
Immersive virtual reality; head mounted displays (HMD) and data gloves [5].

force feedback to user and it is known as haptic. The tracing devices which can track user's head, hands, fingers, eyes and feet to enable interaction with the virtual world are also on usage. The sense of display and sounds can make the user fully immersive to virtual environment and feel separated from the real world [18, 20].

4.2 Semi-immersive VR simulation

This system makes the user stand in a room with a rear projection wall, down projection floor, tracking sensors and sound devices (as illustrated in **Figure 3**) on walls with speakers at different angles. The user is made to see everything three dimensionally by wearing eye goggles. The system is not considered a fully immersive simulator since the user can still see him or herself. An example of this system is the cave automatic virtual environment [8].

4.3 Non-immersive VR simulation

This system stands as the least expensive and least immersive of all. By incorporating stereo display monitor and glasses, this system helps user to be involved with 3D environment. Designing and CAD systems makes use of this type of simulations and this can be run on a standard desktop computer with mouse or joystick [18] (as illustrated in **Figure 4**).

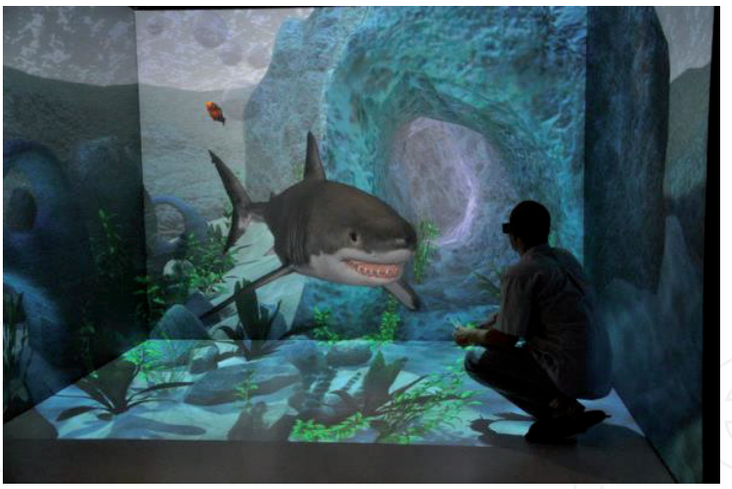

Figure 3.
Semi-immersive virtual reality; cave automatic virtual environment (CAVE) [5].

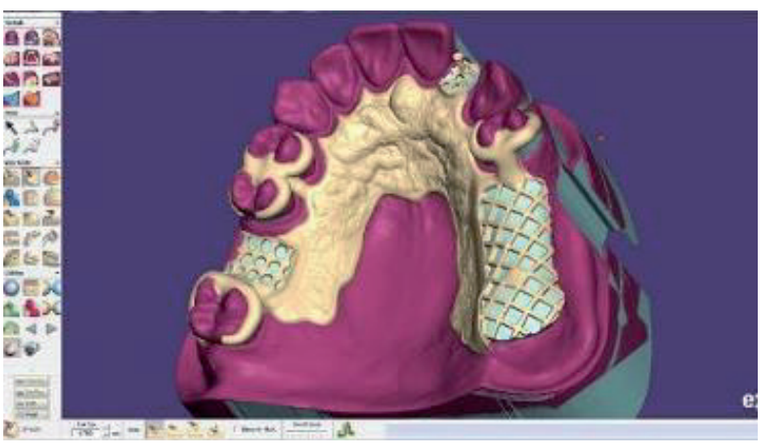

Figure 4.
Computer-aided design system [5].

5. Application of VR in dentistry

Application of VR simulation systems in dentistry is still considered to be a challenge even though its application in different aspects of medical training such as laparoscopic surgery [40], etc., are evident in reality. The difference with dental instruments in type, shape, speed and diversity of oral tissues such as gingiva, multilayer teeth and bone with their own complexity contributes to the reason for difficulty in application of the systems [27].

In the dental virtual reality systems, the operator makes use of the stylus which with the help of worn special goggles, appears as the intended instrument like high or low speed hand piece in 3D displaying stereoscopic monitor, to simulate the tooth reduction [21]. Here, the accurate digitized models of instruments, oral cavity tissues and sophisticated graphic programs for showing reduction of tooth are the factors considered to be mandatory.

Different layers of tooth like enamel, dentin and dental pulp are modelled in VR systems and this helps dental students to avoid unintentional exposure of dental pulp during clinical practice [42]. The haptic devices bring in possibility for the user to feel the force required for each practice (force feedback) and provide a realistic tactile sense and hence the differentiation between various structure or speed of instruments is only possible with the help of haptic devices. These devices paves way for surgeons to touch and feel objects such as surgical tools and human organs in a virtual environment

Concept	Classification	Fully synthetic virtual world	Fully real virtual world	Absolute spatial registration critical	Relative spatial registration critical	Real-time interactivity critical
Augmented reality	Uses computer	No	No	Maybe	Yes	Yes
Virtual reality	Uses computer	Yes	No	No	Yes	Yes

Table 1.
Comparison of virtual reality and augmented reality [5].

to perform procedures like pulling, pushing and cutting of soft and hard tissues with realistic force feedback. Programming of VR simulator to identify errors and assess the quality of performance is an additional advantage. The basis for comparison and assessment is the fact that the experts determine the best performers and errors [12, 13].

6. Augmented reality

In AR, the real environment is not completely suppressed and notably plays a significant role in the process (as shown in **Table 1**), making it contrast to VR simulators. AR refers to super imposition of computer generated graphics of real world scene [7]. Instead of engaging a person in a world that is computer generated, augmented reality aims to add synthetic additives to real world or to a live video of real world [34]. Image guided surgery where real and virtual objects need to be composed, integrated, presented or manipulated simultaneously makes the best use of AR [9]. Wide application of AR is also seen in maxillofacial surgery temporomandibular joint motion analysis, prosthetic surgery and dental implantation [36, 39, 41].

Visualization of deep masked structures is where AR is mainly used in oral and maxillofacial surgery. The surgeon maps the surgical map on the 3D image of the site and considers for any necessary modification before the surgery. In the surgery, the surgeon follows the mapped image overlaid on the surgical site with special glasses during the surgery. Ventures for the development of this system for root canal therapy are on progress. To enhance the training capacity, few systems make use of AR and VR technologies [38].

7. Future of VR and AR in dentistry

Creation of new models for diagnosis and treatment for technically challenging patients can be made possible by the dynamic association of operation on real organ with imaging data. The VR and robotics, as new technologies will have great impact on health care in the near future [19]. This can help experienced surgeons, extending safe limits for more efficient operations [36, 39]. Still there are technological challenges that researchers and developers must face even though VR and AR systems seem to be promising.

8. Dental CAD-CAM systems

Many advanced chair side and laboratory CAD-CAM systems were introduced in the past couple of decades. Data collection, designing and manufacturing has

been made easy by CAD-CAM systems. CAD-CAM in dentistry holds its own significance like manufacturing by milling technologies. However, it is not completely true as manufacturing can either be by subtractive (milling) or additive technologies [16, 28] (**Table 2**).

The CAD-CAM systems consists of three components:

1. A digitization tool/scanner that transforms geometry of real world object into digital data to enable processing by a computer.

2. Software for data processing.

3. A technology which manufactures the desired product from the digitized data set [28].

Different types of materials such as porcelain, composite resin and metallic blocks are used in the manufacturing of many fixed prosthetic restorations. Zirconia, which could not be manufactured by conventional methods previously due to technical limitations can also be manufactured now by these systems [30]. The CAD-CAM systems are going to find substantial applications in implant dentistry to manufacture implant supported prostheses, abutments and diagnostic templates [29].

The main benefit of this in dentistry is that the conventional impressions are not needed anymore, which is believed to save dentist's chair time and eliminate a time consuming step [25]. The CAD-CAM techniques and rapid prototyping are widely used in treatment of maxillofacial defects and surgeries [23]. These techniques are also used for designing and manufacturing the metal components of removable partial dentures by 3D printing [10, 35]. Additionally, this helps in collection of 3D data from the patient's cast, determining the path of insertion and designing the shape of components or frameworks digitally. The completed models are stored as stereolithography files, which are later transferred to rapid prototyping models. Finally, metal removable partial dentures are fabricated by selective laser melting techniques [24]. Various factors like orthodontic diagnosis, treatment planning [26] and fabrication of appliances (Invisalign production process) which include submitting of scan or impressions and photographs to the company with doctor's instructions. Making use of CAD-CAM technology these intraoral scans or impressions are used to design accurate 3D digital models for each dental arch after which

Advantages of CAD/CAM systems	Limitations of CAD/CAM systems
No need for traditional impressions when intraoral scanners are used	High cost
Chairside fabrication of restorations	Need mastering of technology
Fewer visits	Manual veneering is used most of the time
Needs less manual procedures in laboratory	
Needs less laboratory time	
Easier laboratory procedures	
Good marginal accuracy	
Suitable for materials like zirconia	

Table 2.
Advantages and limitations of CAD/CAM systems [5].

stereolithographic model is fabricated for each step. Then a plastic aligner will be made over each model and the set of aligners are then sent to the practitioner [37].

Determination of impacted maxillary canines and fabrication of occlusal splints are also done with this. Comprehensive visualization and records of the craniofacial complex are important goals in orthodontic imaging which have been conventionally achieved by means of plaster dental casts, photographs and radiographs. However, cone-beam computed tomography (CBCT) has gained considerable acclaim worldwide as a viable tri-dimensional (3D) imaging modality [3].

1. CBCT is a medical image acquisition technique based on a cone-shaped X-ray beam centered on a two-dimensional (2D) detector. The scanning software collects the raw image data and reconstructs them into a 3D data set.

2. Whenever it is necessary to comprise the whole craniofacial region in the study, as in cases of cephalometry analyses, a large field of view (FOV) must be selected, which, according to the American Academy of Oral and Maxillofacial Radiology.

3. Captures a spherical volume diameter or cylinder height >15 cm.

4. However, CAD-CAM additive manufacturing innovations have not been used successfully for a wide range of removable orthodontic appliances [26].

Virtual articulator, a basic tool in the CAD-CAM systems, deals primarily with functional aspects of occlusion and is a core tool in many diagnostic and therapeutic procedures [2] (as shown in **Table 3**). According to GPT 8, an articulator is defined as,

> *"A mechanical instrument that represents the temporomandibular joints and jaws, to which maxillary and mandibular casts may be attached to simulate some or all mandibular movements." There are several articulators available in market today, some are very complex and some are very simple in their use and adjustments. The articulator to be used depends on preference of dentists. The late Carl O. Boucher stated "it must be recognized that the person operating the instrument is more important than the instrument itself. If dentists understand articulators and their deficiencies, they can compensate for their inherent inadequacies."*

Virtual articulators are also called as "software articulators" as they are not concrete 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 virtual articulators are able to design prostheses kinematically. They are capable of simulating human mandibular movements, by moving digitalized occlusal surfaces against each other and enabling correction of digitalized occlusal surfaces to produce smooth and collision-free movements.

The virtual articulator offers the possibility of significantly reducing the limitations of mechanical articulators, due to a series of advantages: full analysis can be made of static and dynamic occlusion, of the intermaxillary relationships, and of the joint conditions, thanks to dynamic visualization in three dimensions (3D) of the mandible, the maxilla or both, and to the possibility of selecting section planes allowing detailed observation of regions of interest such as for example, the temporomandibular joint. Combined with CAD/CAM technology, this tool offers great potential in planning dental implants, since it affords greater precision and a lesser duration of treatment [14].

	Virtual reality	Augmented reality	CAD/CAM systems
Prosthodontics		Diagnosis and treatment planning for implant placement	Fabrication of crown and bridge frameworks Fabrication of custom made abutments for implants Designing and manufacturing of implant surgical splints Designing and manufacturing RPD metal frameworks Designing complete dentures Virtual articulator which used in many diagnostic and therapeutic procedures
Maxillofacial surgery	Training by performing virtual surgery 3D observation of surgical site	Superimposition of radiograph over the surgical site Implant placement during surgery	Making maxillofacial prosthesis
Orthodontics			Diagnosis and treatment planning Determining the position of impacted maxillary canines
Periodontics	Training of scaling	Diagnosis and treatment of periodontal diseases Differentiating between pathological and normal conditions	
Restorative dentistry	Training tooth preparation		Fabricating indirect restorations

Table 3.
Applications of computer-based technologies in dental aspects [5].

9. Conclusion

Today, designing and manufacturing dental appliances and prostheses makes a significant use of computer based technologies. Still, the simulation systems for instructions or dental skills are the new modalities unexplored and used very by few dental practitioners and schools. These systems are under constant progress and development. Like most of the other new technologies, they are too expensive with more maintenance and repair costs. Computer assisted skill acquisition in conjunction with traditional training on the other hand would enable students to practice repeatedly with constant assessment and for feedback which is rarely possible with resin models. Simulation systems enable the students in surgical field to practice in real mode on virtual subjects. Surgeons can make the best use of visual information on surgical site provided.

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