VirTeaSy a haptic simulator for dental education.

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Abstract

Implantology is now in full development. However, although different types of training exist, they all suffer from the same problem: the training by practice. The aim of the project VirTeaSy is to propose for the implantology a solution of global formation, using virtual reality. This article will show the VirTeaSy project from a technical and educational point of view; and explain the contribution of the activity analysis in the design of the simulator.

Keywords: dental surgical simulators, haptic feedback, virtual reality, VET, Activity analysis

1. Introduction

Implantology is a technique which consists in drilling the bone, to put in a titanium artificial root supporting a prosthetic tooth. It includes (1) a phase of planning to make decision on the type of implant and (2) a surgical phase incorporating a set of surgical procedures. This technique is now in full development. A study by the Conseil National de la Formation Continue Odontologique (2009) indicates that training in implantology correspond to 48% of all training opportunities offered to dentists in 2008.

The training development coming from implantology is not or almost not taught in universities. Thus, implantology is taught to dental surgeon in activity. There are three categories of training. Universities offer a 2 years training to pass a diploma. A training is also offered by private formation center or implant manufacturer. Finally the third type is assured by different associations.

In spite of the huge variability between the trainings in term of theoretical contents, time of training or, implemented pedagogy; they all use the same method for practical teaching: plastic jaw, human or animal corpse, or operate under the supervision of an expert. However these three solutions have limits. The plastic jaws don't give a good enough haptic feedback and don't have good support points. Practicing on corpse is expensive, difficult to organize, and you can’t reuse them. In consequence, most students are followed by experts. However, this solution also provides problems: availability of experts, lack of training on certain conditions, risk to the patient involved in a learning situation, training situations not built for educational purposes (Vadcard, 2005).

The VirTeaSy project is developed by DIDHAPTIC1 and is on the market. This project treats all the difficulties that implantology meets using virtual reality. In fact, as we can see in many researchs (Fuchs, 2006 ; Ost & al, 2001 ; Datta & al, 2002): virtual reality is nowadays a serious alternative for pratical training. The objective of the VirTeaSy Project is to design a simulator to

1 http://www.dihadaptic.com/?lang=fr
teach implantology. Therefore, this simulator is within the field of VET (Virtual Environment for Human Teaching). This simulator is provided with a software to help planning operations and a virtual 3D environment, and an arm force feedback to improve the hand skills. The training offer by the simulator is in 2 phases: decision making and surgery performing.

The aim of this article is to present the VirTeaSy project and to show the contribution of the activity analysis in the design of the simulator. Section 2 presents existing simulator in implantology and reviews the pedagogical relevance of each simulator. Educational and technical dimension will be presented in section 3. And in the last section, we will explain the contribution of the activity analysis in the design of the simulator.

2. Overview and limits of implantology simulators.

The use of virtual reality technology has become common in various fields such as aviation, driving or military settings (Salas et al., 2002), but also in the medical field (Liu et al., 2003). Specifically in the field of dentistry, solutions using virtual reality techniques are tested (Luciano, 2006). These solutions borrowed techniques developed in other medical fields: endoscopy, endovascular surgery, hysteroscopy and laparoscopy. Even though complex and realistic medical simulators are becoming more and more common in medical education, the use of simulator in the field of implantology has not been well exploited yet (Luciano, 2009).

Before starting the state of the art, it is important to define the word « simulator ». Simulator is an experimental device or a computer program that can reproduce the real performance of a device for study, demonstration or explanation; using a model or a computer program (Silveira, 2004, p72). So, it is not just computer simulator.

The next state of the art focuses on the simulators for implantology (and dentistry) and review the pedagogical relevance of each simulator. For a complete review of surgical simulators in the medical field, see Silveira (2004) and Vidal et al (2004).

2.1. Typology of implantology simulator.

Simulators can be classified into four categories (Silveira 2004): The anatomical simulator (AS), the virtual simulator (VS), the virtual simulator with force feedback (VSFF), and anatomical virtual simulator (AVS).

2.1.1 Anatomical Simulator (AS):

This simulator is the simplest. It consists of a model representing the anatomy of humans. This type of simulator is called "passive" because there is no interaction with the operator. It may be plastic, cloth, rubber, or deformable materials such as silicone or latex. This type of simulator does not have a visual system.

The system "DSEplus" by Kavo 2 attempts to overcome the difficulties associated with plastic jaws. This system simulates a patient and a complete unit of dental care. The student can adjust the position of the patient, has a suction module, pressurized water module, the entire implantology kit and a foot switch to activate the engine dental hand piece. The mannequin is made of rubber. It includes a plastic jaw as the student can drill using suitable support points. However, this system is rarely used in training in implantology since it was originally designed for dentistry. Moreover, the trainers do not consider useful to make the changes necessary to perform implantology gestures with plastic jaws, given their limitations.

The virtual simulator refers to the use of computer tools. They don't provide interactivity with the operator, except a 3D interface for viewing data. Some of these simulators can be based on mathematical models representing the anatomical and biomechanical behavior of bodies.

The anatomical virtual simulators combine the advantages of anatomical simulators (immersion and interaction with real environment) and benefits of information technology (transducers position and pressure). These simulators are called "active" because they take into account the actions of the operator. They increase the immersion of the operator through the haptic interface, graphics (3D display) and acoustic.

These simulators have the same characteristics that virtual simulator, in addition they provide a force feedback that allows the user to interact with the virtual environment and to feel its movements.

To our knowledge, this type of system doesn't exist in implantology. However, there is an example in dental field: Haptik3 system developed by the company Digisens. It consists of a computer screen with a 3D stereoscopic view of objects, and an arm force feedback in three degrees of freedom for tactile sensations. However, the educational content of this simulator was limited to one exercise. This has greatly limited its use.

The virtual simulator with force feedback seems to offer a real interest in implantology, provided it has an educational content. Because first, they can resolve the majority of problems of other systems and secondly, they can respond effectively to the difficulties identified in the training practical for implantology. The VirTeaSy project is a response to the current lack of such a training solution to the implantology.

3 The VirTeaSy project : technical and pedagogical point of view

3.1 Objectives of VirTeaSy

The objectives of VirTeaSy project is to design a virtual simulator with force feedback for the overall training in implantology. The simulator is intended to train dentists: first in planning the surgery, without 3D interface, based on a set of clinical cases representing the main cases found in practice, and secondly surgical procedures with good feelings and points support representing the different contexts of intervention on human jaws.

To do this, the VirTeaSy project consists of two subsets: VirTeaSy Scan Implant and VirTeaSy Implant Pro. Each subset has a specific hardware and different features but the whole is complementary.

3.2 VirTeaSy Scan Implant

VirTeaSy Scan implant is also called the "student workstation". Its function is to allow the student to choose a clinic case from a database to treat it; to plan this event, comparing his plan to that of an expert and finally to view information on the assessment of its virtual surgery.

The logic of VirTeaSy Scan implant is teaching the treatment planning, remaining as close as possible to traditional training. In a traditional training, the students learn to plan with slices of scanner, and layers representing the database of implants (shape, diameter, length). Planning occurs in two steps: (1) put the slices of the scanner on a X-ray illuminator, select the work slice, and superimposed the layers of the implants. (2) Choose the appropriate implant according to the theoretical rules of implantology.

To follow up the process of traditional training, VirTeaSy Scan Implant was designed as a true "numerical X-ray illuminator". Indeed, the student sees on the touch screen the different slices of the scanner, selects those who are interested in superimposed digital layers representing implants and determine the appropriate implant. Once planning is complete, the student knows the characteristics (shape, diameter, length) of the implant to perform, and its location (location, angle, depth-landfill) in the jaw.

According to the willingness of teachers in implantology, VirTeaSy Scan Implant does not provide 3D reconstruction of the jaw (see Fig. 1). Therefore the student must be able to achieve
this mental reconstruction to anticipate the result of planning. Furthermore, the simulator has a pedagogical purpose. First, it is able to provide important information to consider. Secondly, the student can compare in real time its planning with the expert one. The expert's planning is detailed step by step and connected to academic courses. Finally, the simulator has a database of clinical cases which were selected by experts in implantology training, to represent all the difficulties we may encounter in implantology.

3.3 VirTeaSy Implant pro

VirTeaSy Implant Pro is also called the "simulation workstation" (see Fig. 2). Its function is to allow the student to perform virtual surgery cases planned in VirTeaSy Scan Implant. Indeed, VirTeaSy Implant Pro reproduces a virtual patient from the scanner of a real patient. This virtual patient has the same anatomical characteristics (bone density, shape and size of jaw and anatomical structures) that the real patient. The student will therefore follow the planning defined in VirTeaSy Scan Implant in order to succeed the virtual surgery in the VirTeaSy Implant Pro.

Moreover, to achieve all operations in the virtual (sequence of drilling, making measuring, implant placement) and to advance the learner, the simulator needs a system of force feedback, a visualization system, a system of assessment and help, and an interface for teachers.

The force feedback is essential to make realistic training on surgical simulator (Chase et al, 1997). So we had to reproduce the dentist’s sensations during drilling of the jaw. To do this, the system VirTeaSy Implant Pro uses an arm force feedback. This arm is the Virtuoso™ 6D Desktop by Haption4. It is composed of three parts hinged motor, which provide a force feedback on the axis translations and rotations, which can act on the six degrees of freedom. This arm can work in a spherical volume of ten centimeters of diameter. Moreover, at the end of the arm force feedback, there is the tool set of the dentist (the cons angle). Thus, the learner manipulates his usual tool, while receiving accurate and realistic sensations during drilling of the jaw. The updating frequency of the arm force feedback is 1000 Hz, which is the value recommended by Liu et al (2003) in their study of surgical simulators.

To observe the virtual patient, VirTeaSy Implant Pro uses stereoscopic glasses (Emagin Z800 3D Visor5) with two opaques screens and a tracking system with six degrees of freedom (“Patriot” by Polhemus6). The head movements of student are reflected in the virtual world, allowing him to navigate intuitively. The updating frequency of the display is 60 Hz: twice upper to the recommendation of Liu et al (2003).

VirTeaSy Implant Pro is able to evaluate the learner's actions according to the planning. Indeed, for each drilling, the student can know the difference between what he did and what he planned (or what the expert had planned) aiming at the drilling's localization, angle and depth.

In addition, a system of help is available. This help may be active or not, according to the will of the teacher or student. They affect:

• Location: a cross appears where drilling should be conducted,
• Angle: a cone of color indicates the ideal angle for drilling.

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5 http://www.emagin.com/products/systems/systems.php
6 http://www.polhemus.com/?page=Motion_Patriot

Fig. 1: View of a patient
• Depth: a measure in real time shows up the depth at which the drill is, compared the top of the peak bone,
• Overheating of the bone: a gauge of color indicates the level of overheating of the bone.

At the end of surgery, the learner can see the effects of its actions on the scanner. Finally, surgery is recorded. The student can look at his surgery with his point of view or with another point of view (such as the assistant for example).

VirTeaSy Implant Pro has a screen deported. This screen is real-time interface between teacher and student performing a virtual surgery. The teacher can look at the actions of the learner, with the chosen point of view. It can also:
• Zoom in on the scene,
• Adjust the help based on student needs
• Assess the drilling of the student by checking the real time scanner of the patient.
• Finally in the near future we plan to implement a function that enables the teacher to cause complications and thus to change the scenario of the intervention at its convenience.

This screen is also a support for the teacher to comment, for the other students, what do the student who perform the virtual surgery. Teachers can give advice, explain the reasons for success or failure. This feature makes it possible to maintain attention for students who do not manipulate the arm force feedback.

3.4 Interaction between the two subsets:
VirTeaSy system
The two subsets VirTeaSy Scan Implant and VirTeaSy Implant Pro are complementary. The learner begins by planning the case on VirTeaSy Implant Scan, then transfer the data from the planning to VirTeaSy Implant Pro. These data will be used to evaluate operations and adjust the help. Once surgery is complete, the result of the evaluation and the record of the surgery are transferred to VirTeaSy Scan Implant. Thus, the student returns to VirTeaSy Scan Implant to look at his surgery, and conduct an reflective and retrospective activity of his actions. Finally, he can extend his learning by consulting academic courses in connection with the case treated, or by performing a new virtual surgery. So we have a learning loop implementation: preparation-perform - back on its own activity - regulation.

The system architecture allows to separate (1) actions requiring a simple computer (2) actions requiring the arm force feedback and 3D glasses.

A student spends on average five times more time to plan (and come back on his actions and consult academic courses) than to perform virtual surgery. That is to say that the student will use five times more "workstation student" that the "workstation simulation". This observation leads us to design an organization of classroom with one VirTeaSy Implant Pro for five VirTeaSy Scan Implant, which allows to optimize the training costs per student.

4 Activity analysis to design a simulator
To carry out this project, we adopted a multidisciplinary approach, combining skills in virtual reality (for designing the virtual reality devices), computer science (algorithms for designing
mechanical simulation and obtain a sensory realism in applications), and pedagogical engineering (to analyze the activities of practitioners and develop pedagogical content).

This fourth part will focus on the last skill: an analysis of the activity. The theoretical framework mobilized to carry out the activity analysis is the "didactique professionnelle" (Pastré 1999). The objective of this analysis is to characterize the expert in implantology. To do this, we record ten implantologist’s experts in situ: during a real surgery. Then, we conducted self-confrontation interviews with each implantologist recorded. During these interviews, the implantologist look at the video of his surgery and explains its activity with the assistance of the researcher.

From analysis of these interviews, we were able to extract several important information which helped us in designing the simulator VirTeaSy. This important information will be detailed in this section.

4.1 The situation

One central point in activity analysis is the distinction between task and activity. Indeed Leplat (1997) showed that there is always more in the real work (activity) than in the prescribed task. And it is the analysis of the gap between the prescribed task and real activity that will help us to identify the meaning of activity of the implantologist. Our analysis will proceed in two phases: an analysis of the task and activity analysis of implantologist.

With the analysis of the prescribed task, we identified the tools needed to the surgery, the sequence of actions, and the organization of the room. With the analysis of the activity of the implantologist, we identified the meaning of the actions and the meaning of the tool's location. And with this meaning given by the expert, we could identify the important elements for a successful implant surgery and the minors elements.

Therefore only the important information (needed for learning) have been implemented in the simulator, and all elements not specific to implantology or not essential have been set aside.

4.2 The hand skill

Similarly, we conducted a very detailed analysis on the gesture of implantologist during surgery. What interested us were the positioning of the surgeon, the hand position relative to the workspace, the positioning of support points, and the force exerted on the tool.

The conclusion of this analysis is that there is huge variability among practitioners, and it is impossible to define a typical gesture. Therefore, we have conducted several experiments (paper being written) to design an ergonomic workstation to respond optimally to this variability. Although the support points vary between practitioners, all in taking. The support points are extremely important. Thus we have added a physical jaw with his chin for implantologists can take realistic points of support.

4.3 The main difficulties in implantology

The activity analysis of implantologists (not of the task) allowed us to determine the steps, actions, conditions that posed difficulties in the surgery. We have identified and classified these difficulties. Then to help learners to overcome them, we have created workshops: some decontextualized environments where the student can work specifically on a difficulty.

For example, one of the difficulties of the implantology is to determine the bone density of the jaw, just with the sensations during drilling. This skill is important because the surgical procedure must be adjusted according to bone density, and the scanner does not determine it accurately.

Explanation of the workshop : The typology of bone density shows that there are four types of bone (d I, d II d III, IV d). Therefore, we have made four blocks representing the four types of bones. The objective is to drill each block and recognize its bone density. For that, initially, a label
indicates the density of the block. The learner drills each block: the goal is to combine a type of bone with a sensation (haptic feedback). Secondly, we remove the labels and change location of the blocks: the goal is that the learner recognizes the density of the bone block just using sensations (haptic feedback).

4.4 Pedagogical content
As we saw in the introduction, the best training method in implantology is to perform a real surgery with an expert. But with this training method, the teacher relies on cases that come to the hospital. Therefore, it does not define teaching modules with learning objectives based on a classification of patients. But he treats the patients in the order they appear.

The activity analysis allowed us to characterize and classify each case and identify the "simple case" in implantology. Following this, we have defined pedagogic modules, which are divided into pedagogic objectives.

Specifically, we define the simple case as the putting of a single implant recessed between two teeth at the level of a mandibular premolar. Furthermore, we identified three pedagogical modules (put a single implant, put several implants, put implants on a toothless patient). Within each module, we have identified five pedagogical objectives (perform a simple case, dealing with anatomical difficulties, dealing with orientation and parallelism problems, dealing with aesthetic issues, dealing with multiple difficulties).

5 Conclusion
The aim of this article was to present a training solution to the implantology using virtual reality. The state of the art has shown that in the field of implantology, there is no virtual reality device to train at the planning phase and the surgical phase. VirTeaSy is part of category of the virtual simulators with force feedback. It is composed of two complementary subsets: VirTeaSy Scan Implant and VirTeaSy Implant Pro. The first allows to plan a case, to consult academic courses and to conduct a retrospective and reflective activity on its actions. The second allows to perform a virtual surgery. Finally, we saw how the activity analysis of dentists has allowed us to design this simulator.

However, the design of such a simulator is not the end. It allows starting a second project called "Formarev. The aim of this project is to evaluate the simulator. What skills are learned by students through the simulator and how fast? Is there a transfer of skills learned in the simulator to reality? The training through virtual reality is as good as traditional training? To answer these questions, we are currently conducting a test to compare traditional training to training in virtual reality. To do this, we have three groups. The first group follows a traditional training, using plastic jaw. The second group follows a training using virtual reality, with the simulator VirTeaSy. The third group is a control group: there is no training. All participants are novice in implantology but hold the diploma of dentist. Finally, participants in the three groups must put an implant on a human corpse. What interests us here is to compare the performance of the implant's location between the three groups. To do this we use two indicators: the axis of the implant and its depth. The results of this research are being analyzed.

References


