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Pedagogy

Proposal of Educational Models and a Simulation Program for Learning Piezosurgery in Stomatology, Implantology and Maxillofacial Surgery

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Abstract **Original Research Article**

Background and Objective*:** The acquisition of technical skills, using piezosurgery devices, would be facilitated by simulation on educational models. This study aims to disseminate a simulation program and propose educational models of animal origin enabling progressive achievement of psychomotor skills in learning piezosurgical procedures. ***Material: As part of the national continuing education program in stomatology, implantology, and maxillofacial surgery that we founded and have been leading since 2015, seven procedural simulation sessions for piezosurgery training were realized. The simulation program included two steps: first, specific tasks carried out on a sheep's head to learn psychomotor skills using piezoelectric device. Then, similar tasks were reproduced on a hen egg to reach a higher level of mastery and proficiency. The program and simulation models were evaluated according to a questionnaire by 200 practitioners at the end of each session. ***Results:*** Almost all participants reported that working on a sheep head authentically reproduced the tasks, that were completed after at least two attempts, with a feeling of projection into the clinical environment. All participants considered that undermining the membrane from the eggshell reproduced the same gesture on the Schneiderian membrane. However, only 30% of practitioners achieved this task on the hen egg requiring more than five attempts. ***Conclusion:*** The simulation program using the educational models that we have proposed allows us to carry out in the first stage of the simulation the basic learning of technical gestures in a high-fidelity environment and the second stage considered as an advanced simulation, to acquire a higher level of competence and technical capacity. Our simulation method is simple, inexpensive, and reliable to become standardized and followed on a larger scale in learning piezosurgical skills.

Keywords: Piezosurgical skills; Pedagogy; Simulation; High-fidelity; Educational models; Practice-Based Learning and Improvement; Medical Education.

INTRODUCTION

Simulation-based surgical education is increasingly used worldwide as a teaching tool in medical training programs. Its effectiveness has been proven in initial and continuing medical education. Indeed, simulation training in medical education is consistently associated with significant effects on skills, knowledge, and behavior outcomes, and thus improved patient care (Cook DA *et al.*, 2011; Brydges R *et al.*, 2015)which should continue to improve mainly in surgical practice, as for the use of piezosurgery in the oral and maxillofacial field.

The use of piezoelectric devices offers greater precision and safety in bone surgery than with conventional rotary drills, concerning bone necrosis and soft tissue lesions mainly oral mucosa, nerves, and maxillary sinus membrane (Mehri Turki I, 2015; Aly LAA, 2018). However, practitioners may be hostile to changing their surgical habits and do not dare to discover new technologies, especially when there is a need for learning that encroaches on working time. Therefore, planning procedural simulation sessions during continuing medical education, such as those carried out in this study, constitutes an alternative to carrying out these simulation workshops to introduce this new technology and ensure adequate learning to acquire psychomotor skills consistent with current practice. This study aims to present an original and reliable simulation program using a combination of educational models, which we have proposed, to provide basic learning of piezosurgical skills in a high-fidelity setting and then to improve technical abilities using paradoxically a low-fidelity educational model.

METHODS

As part of the national continuing education program in stomatology, implantology, and maxillofacial surgery that we founded and have been leading since 2015, seven procedural simulation sessions for piezosurgery training were realized, involving 200 participants. The inclusion of participants in the study was based on the order of their registration which was free of charge. Exclusion criteria were previous experience with piezosurgical devices. Thus, participants are novices in the use of piezosurgery. As this study was conducted in a non-clinical setting, the institutional ethical committee approval is not required.

The instructor, who is the author, an experienced maxillofacial surgeon in piezosurgery, presented the progress of the simulation program (Figure 1) and then provided a theoretical presentation with digital support regarding piezoelectric equipment, and the advantages of its use. A 15-minute instructional video demonstrating basic piezosurgical principles and techniques was shown. Thus, the training began as follows: fresh hen's eggs and a fresh sheep head were provided for each practitioner. The butcher prepared the sheep's head without fleece. Participants were asked to perform the following four specific tasks respecting imperatively this order: 1- bony window osteotomy exposing the mandibular nerve without creating a bone fracture; 2- bony window osteotomy of the maxillary sinus with an undermining of its membrane; 3- vertical and horizontal dental section; and 4- Rectangular harvest of the eggshell following by the membrane undermining using piezosurgical device without causing its perforation. The 4th task was only carried out when the instructor considered that the two previous tasks 1 and 2 had been correctly performed. Instructions were given regarding the sequence of task progression, the use of equipment, and the confidentiality of practitioners. Otherwise, the instructor was available for explanations, and individual assessments without intervening in the execution of the tasks. At the end of the procedural simulation, a questionnaire was distributed to ascertain their impressions of both educational models value and their overall opinion of the simulation program used in the study (Table 1). The responses were written anonymously. Then feedback was carried out through interaction between practitioners and the instructor. A descriptive analysis of the provided answers was performed.

RESULTS

200 practitioners experienced this procedural simulation in 7 sessions where the number of participants varied between 25 and 30 practitioners per session. They were dentists and oral and maxillofacial surgeons who never used piezosurgical devices in clinical practice and never experienced such a simulation. They were novice practitioners in the piezosurgical practice.

The harvest of bone windows at the mandibular and maxillary level with exposure of the mandibular nerve and undermining of the sinus membrane was successfully performed (Figure 2, Figure 3). The achievement of these tasks required more than two attempts for all participants. Almost all participants performed an easy dental section at the first attempt while the eggshell cleavage from its membrane, requiring eggshell section and membrane undermining, was achieved by only 30% of practitioners following more than five attempts (Figure 4, Figure 5).

The collection of responses to the questionnaire with a descriptive analysis leads to the results presented in Table 2. Most practitioners considered that the hardness of the sheep's jaw bone is similar to that of the human mandibular bone (96.5%), as well as the morphology of the maxillary sinus and tissue properties (86.5%). In addition, 99% of practitioners felt projected into a real environment when manipulating the sheep's head bone (maxillomandibular region and oral cavity). They all argue that piezosurgical procedures performed in sheep's heads are perfectly translated to be done in humans. 82.5% of practitioners considered performing the tasks on the egg is a task with a high level of difficulty, while all agreed that undermining the membrane from the eggshell was conducted similarly to that of the Schneiderian membrane. All participants found that the combination of simulation models allowed them to learn the most common procedures in piezosurgery while acquiring better control of the psychomotor skills and correct use of the piezoelectric device. In addition, the simulation method allowed all practitioners to learn progressively, tending towards an ever-higher level as the technical tasks progressed as well as when the simulation model varied.

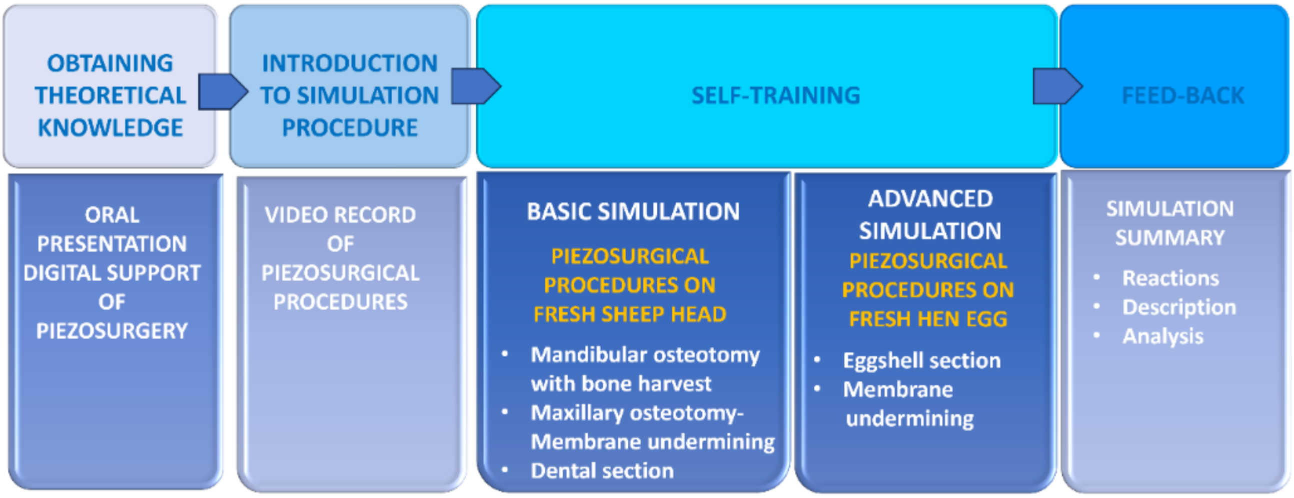

Figure 1: Simulation program for learning piezosurgical skills

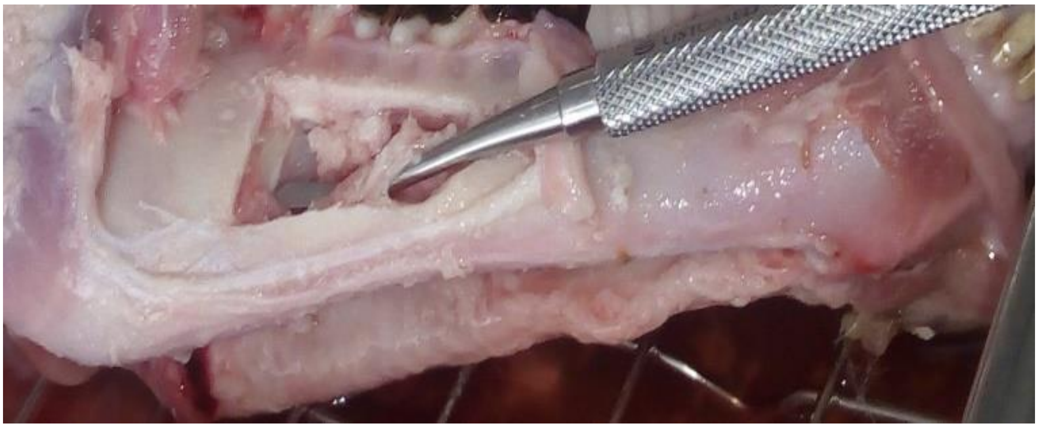

Figure 2: Bone harvest using a piezotome from a sheep mandible showing the nerve above the instrument

Figure 3: Appearance of a bone harvest from the maxilla of a sheep performed with piezotome, with a clean section and intact sinus mucosa

Figure 4: Section performed on the eggshell by ultrasound microvibration emitted by the piezoelectric device shown in the photo

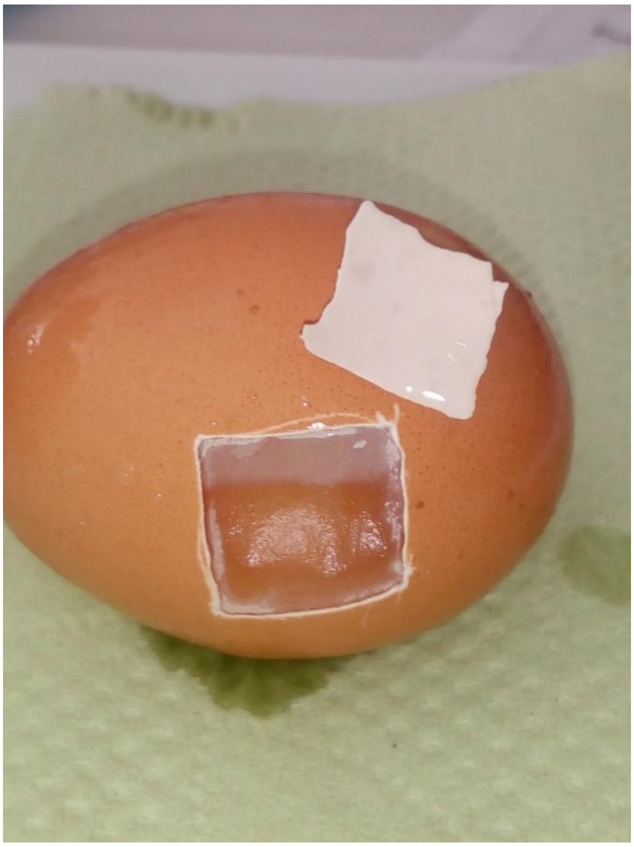

Figure 5: Result of the advanced simulation achieving the egg membrane undermining from the eggshell fragment

Table 1: Questionnaire for assessing the pedagogic value of the educational models and the simulation program

Question Numbers	Statement	Yes	No
Q1	Do you consider that the proposed educational model (sheep's head) presents bone tissues close to the mandible and maxilla of humans?		
Q2	Is the hardness of the sheep's jaw bone close to the human mandible when performing the osteotomy?		
Q3	Can the sheep's head be used as a model to reproduce piezosurgical procedures performed on humans in the oral and maxillofacial field?		
Q4	Are the maxillary sinus morphology and the sinus membrane of the sheep similar in anatomy and tissue properties to that of humans?		
Q5	By performing the section with a piezotome, is the hardness of sheep teeth similar to that of humans?		
Q6	Does the manipulation of the jaws and the oral cavity of the proposed model (sheep's head) project you into the real environment (maxillomandibular region of humans)?		
Q7	Does the act of undermining the eggshell's membrane appear similar to that performed on Schneiderian membrane in humans?		
Q8	Does using the eggshell as a model help you better manage manual pressure when handling the piezotome?		
Q9	Is it easy to separate the membrane from its eggshell using the appropriate insert?		
Q10	Did the combination of two educational models allow you to progress in learning and mastering technical gestures?		
Q11	Did the educational models offered (sheep's head or eggshell) help when you learned the technical gestures of piezosurgery most commonly used in the oral and maxillofacial field?		
Q12	Did the combination of using both educational models allow you to master the use of piezoelectric equipment better?		
Q13	Does the experienced method of procedural simulation allow you to learn gradually to achieve accuracy and proficiency?		

Table 2: Statistics of responses to the questionnaire

Responses / Questions	« YES » Number	« YES » %	« NO » Number	« NO » %
Q1	185	92,5	15	7,5
Q2	193	96,5	7	3,5
Q3	200	100	0	0
Q4	173	86,5	27	13,5
Q5	198	99	2	1
Q6	198	99	2	1
Q7	200	100	0	0
Q8	197	98,5	3	1,5
Q9	35	17,5	165	82,5
Q10	200	100	0	0
Q11	200	100	0	0
Q12	200	100	0	0
Q13	200	100	0	0

DISCUSSION

With the technological innovation in medical equipment, current training in psychomotor skills using these devices makes increasing use of virtual-reality simulation and computer-based video instruction. However, controversies exist regarding their beneficial effect on learning and improving surgical skills translated into clinical performance (Hogle NJ *et al.*, 2008; Xue M *et al.*, 2024). On the other hand, simulation-based surgical skills training represents a new horizon in medical education. It is highly recommended in piezosurgical skills training to provide a safe environment for practitioners to perfect their psychomotor skills and rigorously evaluate their performance without exposing patients to risk (Tavakol M *et al.*, 2008).

Piezosurgery, a relatively novel technique invented by Professor Vercelloti and published in 2000 (Vercellotti T, 2000), is based on ultrasonic micro-vibration created by the piezoelectric effect resulting in oscillations of ultrasonic frequency of 25−30 kHz.

Piezoelectric device has a control panel with a digital display to set the power and frequency modulation. The inserts connected to the tip of the hand-piece, which are titanium or diamond coated, specifically designed to be sharp or blunt, move by micro-vibrations created in a piezoelectric hand piece which when applied with slight pressure on bone tissue results in cavitation phenomena and thus a cutting effect exclusively on mineralized tissue (Mehri Turki I, 2015; Schlee M *et al.*, 2006; Schlabe J *et al.*, 2021). Thus, it avoids soft tissue damage such as the mandibular nerve and Schneiderian membrane. However, an increase in working pressure above a certain level impedes the vibration of inserts transforming the energy into speed. Otherwise, an over-level of hands-on pressure originates in Schneiderian membrane perforation. Thus, adequate dexterity and gentle touch controlling pressure are required for this type of procedure, relatively complex for beginners.

It has been reported that the effectiveness of simulation in surgery and the transfer of skills from the model to the operating room has been demonstrated for the acquisition of basic gestures in novice surgeons, regardless of the type of model used (Grober ED *et al.*, 2024). However, this fact cannot be considered in the training of piezosurgical skills, since real bone sensation is required, and the management of manual pressure according to the degree of tissue mineralization is important. This makes the appropriate choice of simulation models difficult. To our knowledge, there has been no report in the literature of simulation-based piezosurgical skills training in the oral and maxillofacial domain which is strongly recommended before its implementation in clinical practice. So, there is currently a pressing need to expand simulation by devising and validating new easy-to-use models for improving piezosurgical skills and developing standardized simulation programs. However, problems concerning the validity and reliability of educational models, whether of “high-fidelity” or “low-fidelity”, particularly in learning piezosurgical skills may need to be investigated even more to decide whether to use them as a tool for specific surgical tasks.

The results of this study highlighted that the fresh sheep head can be considered as a "high-fidelity" simulation model since the participants found a strong similarity between human anatomy and tissue properties allowing them to approach the most commonly used procedures in piezosurgery. In addition, the execution of different tasks on the sheep's head made them project themselves into a work environment close to reality. Our choice of the fresh sheep head as an educational model is also corroborated by a published report highlighting that the volume of the maxillary sinus, calculated with CT measurement in humans and with CBCT in sheep, appears quite similar in humans as for the average thickness of the maxillary sinus membrane. However, it has been reported that the cortical bone of pigs is very hard and difficult to drill and despite the findings that the thickness of the lateral bone wall of the maxillary sinus is greater than that in humans (Valbonetti L *et al.*, 2015), which has not been experienced by practitioners in this study, we argue that the use of sheep is more suitable than using pig head in piezosurgery simulation.

Although the hen egg, which to our knowledge has never been described in the literature in the context of simulation, is a "low fidelity" educational model, it was found in this study that it was difficult to accomplish the requested task unlike when it was performed on the sheep's head. Indeed, the pressure of the hand when using the handpiece must be highly controlled so as not to crush the egg or perforate its membrane. This model makes it possible to perform the task with an even higher level of precision and skill. In addition, this simulated gesture seems more difficult to perform than on the patient, particularly in cases of sinus floor elevation. Thus, its success could offer autonomy and confidence in performing this procedure on the patient. Therefore, performing surgical tasks on "low fidelity" educational models rather than on animal models is not systematically easier as experienced in this simulation which combines two educational models with a particular order of task performance allowing a progressive learning curve in one day of training.

Furthermore, it has been reported that the effectiveness of motor learning is, to a large extent, the result of the optimized motivational states of the learner (Wulf G *et al.*, 2005). Therefore, we support that the execution of the same tasks when increasing the level of difficulty by varying well-adapted educational models provides gradual learning of psychomotor skills while increasing the challenge of succeeding which increases the motivation for success, and thus learning surgical skills will be optimized.

CONCLUSION

Simulation-based surgical education is scarce in oral and maxillofacial surgery and is not reported for learning presurgical skills. The main difficult feature remains the choice of the educational model that gives satisfaction. This study highlights the proposal of the sheep head as a “high-fidelity model”, and the hen egg as a “low-fidelity” model contrasting to its use for the acquisition of high-level skills. Thus, this model should change the paradigm in surgical simulation when seeking models of “high-fidelity” usually expensive to enhance skills.

Otherwise, the fresh hen egg and the sheep head are reliable, inexpensive, and available teaching models for the progressive learning of piezosurgical skills. In addition, the successive use of these educational models in the basic and advanced simulation program allows for progressive and consolidated learning by repeating the same tasks. Therefore, we emphasize our experience of a one-day simulation-based surgical teaching program with a skills progression methodology using a combination of the proposed educational models of animal origin. In addition, performing the same surgical tasks following a cascade simulation program makes these gestures progressively difficult and requires even more mastery and bimanual dexterity, allowing the practitioner to promote from the "novice" level to the "capable" level and then to the "competent" level.

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Competing Interest: None

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