How Useful Is Plastination in Learning Anatomy?

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ABSTRACT

In recent years plastination has begun to revolutionize the way in which human and veterinary gross anatomy can be presented to students. The study reported here assessed the efficacy of plastinated organs as teaching resources in an innovative anatomy teaching/learning system. The main objective was to evaluate whether the use of plastinated organs improves the quality of teaching and learning of anatomy. For this purpose, we used an interdepartmental approach involving the departments of Veterinary Anatomy, Human Anatomy, Veterinary Surgery, and Education Development and Research Methods. The knowledge base of control and experimental student groups was examined before and after use of the fixed or plastinated resources, respectively, to gather information evaluating the effectiveness of these teaching resources. Significant differences ($p < 0.001$) between control and experimental groups of Human and Veterinary Anatomy were observed in the post-test results. The Veterinary Surgery students had the most positive opinion of the use of plastinated specimens. Using these data, we were able to quantitatively characterize the use of plastinated specimens as anatomy teaching resources. This analysis showed that all the plastinated resources available were heavily used and deemed useful by students. Although the properties of plastinated specimens accommodate student needs at various levels, traditional material should be used in conjunction with plastinated resources.

INTRODUCTION

Many sources describe different options to enhance anatomical learning by students through increased motivation, including the use of live animals;[1] the use of prosections versus dissections;[2,3] learning without cadavers;[4] the use of problem-based learning (PBL);[5] the use of virtual-reality surgical simulators;[6] the use of computer-aided instruction;[7] and the use of modular resource centers.[8] Plastinated specimens have also been used as resources to improve the quality of teaching and learning of anatomy, as well as of pathology. Plastination[1] is the most important technique recently developed for the preservation of biological specimens. It keeps thoroughly dissected specimens from deteriorating, thus providing time to prepare new specimens to be added to the anatomical collection. Since its introduction,[9] it has gained wide acceptance throughout the world. The *New Plastination Index* available on the World Wide Web contains nearly 1,000 references.[10] (This Web site is a cumulative index that includes everything published on plastination, from the first paper to the most recent; it is the continuation of the two indexes published in 1996 and 2000.) In particular, the major use of this technique is in the production of a wide range of anatomical specimens for teaching, and it has been considered an important tool in recent proposals for teaching anatomy.[8,11,12] During a recent International Conference on Plastination (held in July 2004 in Murcia, Spain), 75% of oral and poster presentations were related to anatomy education.

The potential value of plastination in research is increasingly being appreciated.[13,14] The plastination methodology consists of slowly replacing tissue fluids and a portion of the tissue lipids with a polymer, under vacuum. The results are clean, dry, odorless, and durable real biological specimens that can be handled without gloves and do not require any special storage conditions or care. These specimens also prevent exposure of staff and students to the toxic substances (e.g., formaldehyde, phenol, alcohols) used in classical preservation of biological tissues.

Plastinated specimens have been used with different diagnostic imaging methodologies that see anatomy from a new perspective[11,12] or with a script and an integrated set of anatomical materials in a modular resource center.[8] Several different applications of plastinated resources have been described. Lozanoff[15] has illustrated a method for developing animations using plastinated brain sections and has demonstrated how realistic anatomical animations can be generated quickly and inexpensively for use in medical education. No evaluations of the impact of using these plastinated resources for teaching, however, were found in a literature search.

The evaluation of teaching resources should be a systematic process of gathering, analyzing, and interpreting reliable information. The evaluation should establish merit or value judgments that will lead to a generalized improvement in the selected teaching materials. Teaching materials represent a basic resource in the present curriculum. Their selection and use provide the basis for achievement of proposed objectives. Since only a few teaching resources have been evaluated, we designed this project to assess the effectiveness of a selection of plastinated organs, and to do so we enlisted the assistance of the Education Development and Research Methods group of our university. The main goal of this study was to evaluate the use of plastinated organs as a resource for teaching anatomy.

MATERIAL AND METHODS

Evaluation of the impact of plastinated specimens on the outcome of student learning was requested by the Veterinary Anatomy investigation group. This investigation involved instructors and students from three university courses (see Table 1). The study protocol was approved by the Institutional Board of Ethics. The students involved were all those attending regularly scheduled laboratory sessions for the three courses, while the instructors involved in the project were volunteers. The students were randomly assigned to control and experimental groups. They were studying three different subject areas: veterinary anatomy (first year of veterinary degree), human anatomy (first year of human medicine degree), and veterinary surgery (fourth year of veterinary degree). Following the study, special lab sessions were set up to allow students from the control groups to work with plastinated specimens.

During the lab, students in the control groups used wet organs and anatomy sections preserved with classical fixative solutions. Students in the experimental groups used only the plastinated specimens. Instructors demonstrated and explained all these anatomy learning resources to the students during the laboratory teaching sessions. The decision on which plastinated specimens should be used was reached by consensus, in response to the needs of the different subjects taught (Table 2). This biological material was processed, using the standard silicone technique,[16] in the Plastination Laboratory of the College of Veterinary Medicine, University of Murcia. The evaluation instruments consisted of observation techniques combined with inquiries into previous knowledge and post-tests. For this study, four instruments were selected:

- A closed questionnaire using a three-point numerical estimation Likert-type scale (1 = disagree, 2 = agree, 3 = strongly agree) was filled out by the instructors, referring to the effectiveness of the plastinated specimens as anatomy teaching resources.
- A closed questionnaire using a three-point Likert-type scale (1 = disagree, 2 =agree, 3 =strongly agree) was filled out by the students in the experimental group to gather information relating to the effectiveness of the plastinated specimens as anatomy learning resources. The questionnaire given to the students also included two open-ended items, which asked students to point out the negative aspects of the plastinated specimens and how they would improve them.
- A pre-test examining previous knowledge, made up of 10 questions, was administered to both control and experimental groups. This examination was designed to evaluate the knowledge base of students before the experimental treatment.
- A post-test (output examination), made up of 10 questions (1–10 points in value), was administered to both control and experimental groups in order to evaluate the quantity and quality of the knowledge and skills students had acquired as a consequence of the use of plastinated material.

The items contained in each of the evaluation instruments were developed by the participating instructors from the College of Education (Education Development and Research Methods Group) together with the instructors from the participating university disciplines (Veterinary Anatomy, Human Anatomy, and Veterinary Surgery). The student questionnaire items for each course were formulated for that subject. A 2×2 factorial analysis of variance (ANOVA, $p < 0.05$) was carried out using SYSTAT 11,[a] with type of student group (control or experimental) and time of

Table 1: Participants in the evaluation of plastinated specimens to teach anatomy

Education Center	Subject	Instructors	Students	
			Control Group	Experimental Group
College of Veterinary Medicine	Veterinary anatomy	3	123	110
College of Veterinary Medicine	Veterinary surgery	1	72	67
College of Medicine	Human anatomy	2	38	47

Table 2: Plastinated specimens used for the evaluation

Education Center	Subject	Plastinated Specimens
College of Veterinary Medicine	Veterinary anatomy	Horse cephalic block (22 transverse sections)
		13 whole hearts (pig, sheep, horse, and dog)
		7 hearts (pig), right side opened
		7 hearts (pig), left and right sides opened
		7 cardiopulmonary blocks (dog)
		8 silicone tracheobronchial trees (pig)
College of Veterinary Medicine	Veterinary surgery	Forelimb (horse), 55 transverse sections
College of Medicine	Human anatomy	Head (14 horizontal sections)

examination (pre- or post-instruction) as factors and the marks obtained by students as the dependent variable.

RESULTS

A descriptive analysis of the data gathered by each of the instruments employed was carried out. The questionnaires answered by the students yielded their opinions on the efficacy of the plastinated specimens they used; Table 3 shows the global average and standard deviation for each education center. The results registered by instructors after the use of plastinated specimens, using the three-point numerical estimation scale, are illustrated in Table 4. The average marks and standard deviations obtained on the pre- and post-tests in the various subjects are presented in Table 5 for both control and experimental groups.

DISCUSSION

The initial goal of this analysis was to determine whether the use of plastinated specimens benefits anatomy learning. Instructor and student evaluation responses confirm that both consider plastinated specimens useful. The highest average (2.584/3) of student opinion as to the efficacy of plastinated specimens was observed in the Department of Veterinary Surgery, followed by the Department of Veterinary Anatomy and the Department of Human Anatomy. The majority of references concerning the evaluation of gross anatomy teaching use a simple student questionnaire to obtain results.[1,2,7] However, the three-point Likert scale method used in this work was also used in recent studies to compare the effectiveness of different learning tools between two groups of students.[6,17] The numerical estimation scale used to solicit instructor opinions yielded the highest averages (2.714/3) in the Department of Veterinary Anatomy, followed by the Department of Veterinary Surgery and then the Department of Human Anatomy. These data reveal the effectiveness of the plastinated specimens, at least from the instructors' point of view.

The following conclusions can be drawn from the results obtained in the pre-test (previous knowledge) and the post-test for the control and experimental student groups:

- The pre-test results are homogeneous for both control and experimental groups, meaning that both groups started from a similar level of knowledge (Veterinary Anatomy, $p = 0.993$; Veterinary Surgery, $p = 0.933$; Human Anatomy, $p = 0.681$).
- Students from both experimental and control groups raised their knowledge level.
- Significant differences are observed in the post-test knowledge base of both control and experimental groups in Human and Veterinary Anatomy. The improvements recorded in the post-test of the Veterinary Surgery control and experimental groups are not significant.
- Student results confirm the efficacy of the use of plastinated specimens as teaching resources for two of the education centers, but not in Veterinary Surgery. Students in the Veterinary Surgery group were studying the subject for the second time; they were already familiar with the content of the laboratory class, which explains their high average mark on the pre-test. For this reason, a new evaluation process is being prepared for this center.

Most students did not report any disadvantages to using plastinated specimens of teaching resources. Students

Table 3: Student questionnaire

Subject	# of Students	Mean*	*SD*
Veterinary anatomy	133	2.460	0.256
Veterinary surgery	138	2.584	0.280
Human anatomy	85	2.337	0.316

*1 = disagree, 2 = agree, 3 = strongly agree.

Table 4: Instructors' observations

Subject	Instructor Observations (Mean)*
Veterinary Anatomy	2.714
Veterinary Surgery	2.619
Human Anatomy	2.429

*1 = disagree, 2 = agree, 3 = strongly agree.

Table 5: Pre- and post-test results

Groups	Pre-test		Post-test	
	Control	Experimental	Control	Experimental
Department of Comparative Anatomy and Pathologic Anatomy (College of Veterinary Medicine)				
# of students	123	110	123	110
Mean (/10)	5.862	5.782	6.870	8.100
SD	2.136	2.182	2.673	1.827
Probability $\alpha = 0.05$	$p = 0.993$		$p < 0.001$	
Department of Animal Medicine and Surgery (College of Veterinary Medicine)				
# of students	72	67	72	67
Mean (/10)	6.896	7.037	7.056	7.269
SD	2.158	2.524	1.362	1.109
Probability $\alpha = 0.05$	$p = 0.933$		$p = 0.967$	
Department of Morphological Sciences and Psychobiology (College of Medicine)				
# of students	38	47	38	47
Mean (/10)	6.237	6.596	6.526	7.553
SD	1.866	2.242	1.268	1.544
Probability $\alpha\alpha = 0.05$	$p = 0.681$		$p = 0.047$	

did suggest that the plastinated specimens might be improved as teaching tools if latex were injected into the vessels and if the anatomical structures were labeled with a number and a legend.

The process of fixing anatomy specimens is risky, and the compounds used may pose a significant health hazard. The use of plastinated specimens addresses these exposure issues and prevents excessive exposure of staff and students to the toxic substances used in many embalming fluids. In this study, the use of plastinated prosections was considered useful by instructors and students for teaching and learning anatomy. In the authors' opinion, the use of plastinated prosections and other tools to teach anatomy should be used to complement the dissection experience. This opinion is also shared by other authors;[8,18,19] others, however, believe that these resources should replace the dissection experience.[4,12] Our results also show that the use of cross-sectional plastinated slices to understand ultrasound, computerized axial tomography, and magnetic resonance imaging (MRI) was beneficial, as other authors have indicated.[11,12,20,21,22] As well, specially designed plastinated specimens allow individualized training in endoscopic techniques and skills prior to exploration and surgery on patients.[23,24,25] This methodology should aid the teaching and learning process for minimally invasive surgical techniques. Considering the results achieved with this project, we can assert that the use of plastinated specimens as teaching resources does improve the quality of teaching and learning in anatomy. This kind of teaching material should improve the teaching/learning process in a wide range of subjects (e.g., biology, anatomy, pathological anatomy, surgery, radiology). Specific studies are necessary to validate the use of plastinated specimens for training in the interpretation of diagnostic imaging techniques such us endoscopy, arthroscopy, ultrasonography, MRI, and CT.

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NOTE

a Systat Software Inc., San Jose, CA, USA <www.systat.com>.

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