Surgical and Radiologic Anatomy (2019) 41:1181–1186
https://doi.org/10.1007/s00276-019-02270-3

REVIEW

Outcomes of the use of plastination in anatomy education: current evidence

Dimitrios Chytas[1] · Maria Piagkou[1] · Elizabeth O. Johnson[1] · George Tsakotos[1] · Antonios Mazarakis[1] · George C. Babis[2] · Vassilios S. Nikolaou[2] · Maria-Kyriaki Kaseta[2] · Konstantinos Natsis[3]

Received: 4 November 2018 / Accepted: 7 June 2019 / Published online: 15 June 2019

Abstract

Purpose We aimed to evaluate the quantity and quality of current evidence concerning the outcomes of use of plastinated specimens in anatomy education.

Methods We performed a narrative literature review, searching for papers dealing with the use of plastination in anatomy education. PubMed, Scopus, ERIC, Cochrane, Web of Science and CINAHL complete electronic databases were searched. The following data were extracted: author(s), year of publication, type of study (comparative or not), number of participants, evaluation of statistical significance, educational outcomes and their level according to Kirkpatrick hierarchy.

Results Six studies were eligible for analysis. Five of them evaluated only students' reactions about plastination and one study also assessed their examinations results. There were four non-comparative and two comparative studies. Only a study evaluated statistical significance ($p < 0.05$) with higher score of perception in 2nd year undergraduate medical students, who were more familiar with plastination in comparison to 1st year students. Although the use of plastination was accompanied by positive outcomes in the majority of studies (five out of six), this method was not proved superior to traditional cadavers dissection.

Conclusions The existing evidence about the outcomes of the use of plastination in anatomy education is relatively limited and lacks comparative studies with statistical significant results. Positive students' reactions were generally noted, but further research is needed to clarify if plastination could be of benefit to students' attitude and anatomy knowledge.

Keywords Plastination · Anatomy · Education · Cadaver · Dissection

Introduction

Although anatomy is considered as an important part in medical education, a controversy exists about the ideal method of anatomy pedagogy [22]. Brenner et al. [6] described six techniques of anatomy education: (1) lectures, (2) cadavers dissection by students, (3) inspection of prosected specimens, (4) use of models, (5) teaching of living and radiologic anatomy, and (6) computer-based learning [virtual reality, augmented reality and three-dimensional (3D) reconstruction] [9]. According to Estai and Bunt [9] critical review for anatomy teaching practices, there is no a single method for anatomy education and a combination of teaching modalities is required. Among them, the cadavers dissection is an irreplaceable teaching tool for anatomy learning, especially using 3D printing anatomical images [1]. Nevertheless, postmortem body donation nowadays has significantly diminished, while concerns have been expressed about the difficulty of cadavers' maintenance [8, 14]. For more than two decades the technique of plastination, introduced by von Hagens (1977), comprising water and lipids' replacement by curable polymer [26] became a useful tool for tissues preservation [24]. The innovative technique was also used for the production of transparent body slices, and detailed demonstration of anatomical structures [7, 10, 26].

✉ Konstantinos Natsis
natsis@auth.gr

[1] Department of Anatomy, School of Medicine, National and Kapodistrian University of Athens, Athens, Greece

[2] 2nd Orthopaedic Department, "Konstantopoulio-Patission Hospital", National and Kapodistrian University of Athens, Athens, Greece

[3] Department of Anatomy and Surgical Anatomy, School of Medicine, Faculty of Health Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece

Despite the cost of plastinated specimens [18], the advantage of easy handling and convenient storage makes them preferable than formalin fixed material [11, 15, 18]. Neha et al. [20] and Sora et al. [25] highlighted the educational value of plastination applied to knee and pelvis specimens. Riederer [24] underlined the importance of plastination in anatomy teaching, emphasizing on different plastination protocols and their value in structures depiction [24]. Although plastination is an additional method of anatomy teaching, it cannot replace the traditional dissection. The present study aims to investigate the quantity and quality of the existing evidence about the importance of plastinated specimens in anatomy education. To assess the quality of the current evidence, we evaluated the usefulness of this anatomy teaching method. Kirkpatrick [16] proposed a scale to estimate the impact of various educational interventions. In this context, a narrative literature review was performed to ascertain to which extension the existing literature supports the significancy of plastination in anatomy education.

Materials and methods

Search strategy

Three independent reviewers conducted a search in six electronic databases: PubMed, Scopus, ERIC, Cochrane, Web of Science and CINAHL complete using the key words ("plastination" OR "plastinated") AND "anatomy" AND ("education" OR "teaching" OR" learning"). The search was completed on September 30, 2018. The lists of references of the included papers were searched for relevant studies, which were not initially retrieved. Differences between reviewers were discussed until final agreement. In case of disagreement, the senior author decided.

Inclusion criteria

The studies that were eligible for analysis investigated the impact of plastination in anatomy education, were published in peer-reviewed journals and written in English language. Only papers published after January 1, 2010 were included.

Exclusion criteria

Papers without outcomes concerning the use of plastination in anatomy education, letters to the editor, duplicates, review articles, expert opinion articles and published abstracts from conferences were excluded.

Data extraction

In the present review, the following data were collected from each paper: authors, year of publication, type of study (comparative or not), number of participants, evaluation of statistical significance, outcomes related to the use of plastinated specimens in anatomy education and their level according to Kirkpatrick hierarchy (Table 1) [12, 16].

Results

Totally, 105 studies were identified. Sixty-three irrelevant studies, four published abstracts and 32 studies without outcomes on the education value of plastination were excluded. Thus, six papers were finally included in the current review. A flow chart of our selection process is depicted in Fig. 1.

Overall, five included papers [2, 5, 11, 13, 19] had a level 1 in Kirkpatrick hierarchy, since they evaluated students' reactions about educational process. The study of Baker et al. [3] had a level 2b, since it comprised assessment of students' examinations results, after the implementation of plastination. All studies comprised questionnaires investigating students' opinions about plastination independently and in comparison to traditional cadavers dissection. Two comparative [3, 13] and four non-comparative [2, 5, 11, 19] studies are summarized in Table 2. Only one study [13] had statistically significant results ($p < 0.05$).

Comparative studies

Haque et al. [13] published a questionnaire study including 143 1st and 2nd year undergraduate medical students. The percentage of participants who answered positively about the use of plastinated specimens in comparison to the fresh

Table 1 Kirkpatrick hierarchy [12, 16]

Level 1	Reaction	Relates to participants' opinions on the learning experience
Level 2a	Change of attitudes–perceptions	Relates to changes in the participants' attitudes or perceptions after the educational intervention
Level 2b	Change of knowledge–skills	Relates to the acquisition of knowledge and skills after the educational intervention
Level 3	Behavioral change	Relates to the change of behavior in the workplace due to the educational intervention
Level 4a	Change in organizational practice	Significant changes in the delivery of care, due to an educational program
Level 4b	Benefits to patients	Improvement of patients' health due to an educational program

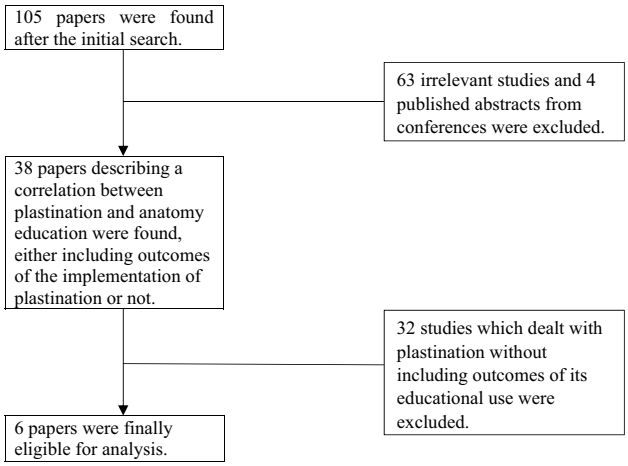

Fig. 1 The flow chart of the selection of the studies in our review

frozen was 46.2%. Approximately 40% of the respondents evaluated that plastination was helpful in identifying structures, and the same proportion of students considered that the plastinated specimens were more difficult to deal with. About two-thirds of participants argued that these specimens did not improve palpation skills, but the same proportion of students preferred dissection of plastinates for a better understanding of 3D orientation of anatomical structures. A percentage of 37.8% stated that plastinates could improve anatomy knowledge, 43.4% that plastinates could replace fresh frozen specimens in the near future and a percentage of up to 22.4% that they could reinforce motivation to learn. About 10% of the 1st year medical students had good perception for the plastination as anatomy education tool, up to 30% had a bad perception and 60% had moderate results. As far as the 2nd year medical students are concerned, the percentages were 30.9, 16.2 and 52.9%, respectively. The mean score of perception was significantly higher ($p < 0.05$) for the 2nd year medical students.

Baker et al. [3] underlined the usefulness of plastination in dental anatomy teaching, in terms of enhancing students' learning experience. According to the syllabus of the School of Dentistry, the objectives of the anatomy course were to: "(1) present the detailed structures of the head and neck in their structural and functional relationships, and (2) teach students to apply anatomical knowledge in daily clinical practice". Forty-two respondents attended the course 2 years before and 35 after the implementation of plastination. The authors noticed that when plastination replaced cadavers dissection in anatomy education, students evaluated that the anatomy course met its objectives up to 91.4%, while this value was 80% regarding cadavers' dissection courses. As far as the National Board Dental Examination grades are concerned, it was clear that they were immediately improved when plastination was introduced, while the failure rate in Anatomical Sciences decreased from 37 to 11% with 40% less teaching hours.

Non-comparative studies

McRae et al. [19] collected the ratings from 103 participants (70 medical students and 33 postgraduate students) about the usefulness of plastination in anatomy teaching of placenta. A percentage of 34.4% of the medical students and 60.6% of the workshop attendees considered plastinates as very useful anatomy education tools (grade 10/10). Almost all respondents rated plastination with a grade from 7/10 to 10/10. Moreover, according to 98.6% of the medical students and 84.9% of the workshop attendees, medical trainees are those who could most likely benefit from plastination. Despite the fact that fresh placentas were considered by over 80% of the participants as the ideal specimen for anatomy learning purposes, 76.7% of the medical students prefer studying anatomy of placenta using plastinates, while 36.7% of them used textbooks or images. As far as the workshop attendees are concerned, the respective percentages were 78.1% and 37.5%. All participants stated that they would like to have plastinated placentas available in the future for educational purposes.

Azu et al. [2] performed a questionnaire study comprising 280 medical students and their perceptions about plastination in anatomy teaching. A percentage of 75% of medical students agreed that plastination would be beneficial to anatomy learning. However, 33.3% of the participants considered

Table 2 The general characteristics of the studies of the review (authors, participants, type, level of outcome according to Kirkpatrick hierarchy, evaluation of statistical significance)

Author (s)	Participants	Type of study	Level	Evaluation of statistical significance
Azu et al. [2]	280	Non-comparative	1	No
Baker et al. [3]	77	Comparative	2b	No
Bhandari et al. [5]	350	Non-comparative	1	No
Fruhstorfer et al. [11]	125	Non-comparative	1	No
Haque et al. [13]	143	Comparative	1	Yes
McRae et al. [19]	103	Non-comparative	1	No

that plastinated specimens could not replace cadavers, although approximately 80% of the respondents argued that plastinates could be used alongside with cadavers. Finally, when students were asked which method they prefer, the percentage was, surprisingly, equal (25.7%) for both methods, while the remaining 48.6% of the students stated that they were uncertain for their answer. Nevertheless, a percentage of 94% wanted to learn more about plastination.

Fruhstorfer et al. [11] published a questionnaire study which comprised 125 1st year medical students. A percentage of 72% of the participants rated the value of plastinated specimens for anatomy teaching as "very good", while 21.6% rated it as ''good''. The students generally argued that they felt minimal emotional distress when working with plastinated specimens, while 43% of the respondents agreed that dealing with cadavers would be more stressful. In terms of promoting anatomy learning, 75% of the medical students supported that plastination motivated them to study anatomy and correlate it with clinical practice. Interestingly, according to about 55% of the participants, fresh frozen cadavers could be adequately replaced by plastinated, although about two-thirds of the respondents would prefer to have an additional cadaveric dissection experience. The qualitative analysis of the study showed that the participants generally identified clearly the anatomical structures, but they pointed out a lack of tactile experience with plastinated specimens, which was considered by some students as fragile and stiff.

Bhandari et al. [5] collected the input from 350 students regarding the use of plastination in anatomy teaching. More than 90% of the respondents preferred the plastinated specimens to fresh frozen in terms of better visualization of the spatial orientation of anatomical structures which help students understand complex structures. All participants pointed out that fresh frozen specimens were more difficult to hold than plastinated, which were non-toxic, light and dry. Nevertheless, fresh frozen specimens were considered as easier to dissect by eight out of ten participants. Interestingly, plastinates were evaluated as insufficient to help students understand adjacent organ relations by more than 95% of the students.

Discussion

Overall, the research regarding the outcomes of the use of plastination in anatomy education is relatively limited and is generally restricted to papers based on students' perception and reactions. Five [2, 5, 11, 13, 19] out of six papers of the current review had a level 1 in Kirkpatrick hierarchy, which is the lowest and indicates that the weak impact of plastination in anatomy teaching. Furthermore, only one study [3] assessed students' test scores and had a moderate level of educational outcome (2b) in Kirkpatrick hierarchy, while there was a complete lack of studies with a higher level of outcome. Moreover, it should be noted that all studies included in the current review, apart from having a low to moderate level of outcome in Kirkpatrick hierarchy, carry a significant risk of bias, since they were not randomized controlled. Additionally, it can be highlighted that only two papers [3, 11] depicted the use of plastination in anatomy curriculum. In the remaining four papers [2, 5, 13, 19], although students' perceptions and reactions were evaluated, insufficient information was provided about the role of plastination in anatomy curriculum. Thus, randomized controlled studies comparing plastination to other anatomy teaching methods are needed to evaluate the contribution of plastination on anatomy knowledge.

The teaching value of plastinated specimens in comparison to fresh frozen is unclear because only two [3, 13] comparative studies have been published so far, moreover, one [13] of them evaluated statistical significance. Although Haque et al. [13] expressed their skepticism about plastination; they found that plastination is more acceptable among 2nd year than 1st year undergraduate medical students. This remark, according to the authors' view, could be explained by the familiarization of the 2nd year medical students with the applied method.

Educational value of plastination

One out of the six aforementioned papers, [13] reported negative opinions about the educational potential of plastination, while the other studies presented generally positive comments. Haque et al. [13], concluded that only a minority of students considered that plastinated specimens could improve anatomy knowledge. Nevertheless, it should be highlighted that this is the only study which statistically evaluated the tendency of a perception. Interestingly, the incidence of good perception among the 2nd year medical students was three times higher than that among the 1st year medical students. However, the majority of the latter (60%) had a moderate perception. McRae et al. [19] pointed out that, although the vast majority of the participants rated positively the educational value of plastinated placentas, they stated that fresh frozen specimens were preferable. However, in the study of Azu et al. [2], 33.3% of the participants considered that plastinated specimens could not replace cadavers, although approximately 80% argued that plastinates could be used alongside cadavers. Additionally, although Fruhstorfer et al. [11] noticed that plastination generally motivated students to learn anatomy, most participants in the study of Haque et al. [13] disagreed. In the latter study, it would be interesting if the authors analyzed separately 1st and 2nd year medical students, and assess their answers regarding plastination.

Outcomes of plastination regarding students' performance

The only study which evaluated test scores achieved after the implementation of plastination was published by Baker et al. [3]. The dental students had a better performance in national board examinations when they studied in plastinated specimens. A remarkable decrease was noted concerning the failure rate in the Anatomical Sciences examinations. The redesign of the course and the implementation of plastination had an important role in test results' improvement. So, there is no evidence that plastination contributed significantly to students' performance in anatomy examinations. Furthermore, a statistical analysis did not take place in this study, so the significance of the aforementioned differences was not clarified.

Ability of plastinates to help students understand the spatial orientation of structures

Three studies evaluated the perceptions of students about plastinates in terms of permitting them to identify structures clearly [5, 11, 13]. Fruhstorfer et al. [11] performed only a qualitative analysis, according to which students stated that plastination served this purpose. However, the lack of a quantitative component reduces the strength of this remark. Haque et al. [13] noted that about two-thirds of the students considered plastinated specimens as helpful regarding visualization of three-dimensional orientation of structures. In the paper by Bhandari et al. [5], 90% of the students preferred plastinated to fresh frozen specimens in terms of visualization of 3D orientation of structures. These two studies showed a tendency of positive students' perceptions concerning plastinates, while there were no papers which demonstrated a superiority of fresh frozen specimens in this field. However, according to Bhandari et al. [5], 95% of the respondents disagreed that plastination was helpful in understanding the organ relationships.

Manipulation of plastinated specimens and tactile experience

Haque et al. [13] and Bhandari et al. [5] demonstrated that plastinated specimens were considered as easier to hold than fresh frozen. Despite this fact, Bhandari et al. [5] showed that plastinated specimens were more difficult to dissect than fresh frozen and about two-thirds of the respondents would like to have an additional experience with cadavers dissection.

Future directions

Although there is relatively limited research regarding the use of plastination in anatomy education, there is robust evidence to highlight the importance of this method in demonstrating clinically relevant anatomy. More specifically, the microvascular anatomy of the talus, whose knowledge is valuable for the design of total ankle replacement prosthesis and the choice of surgical approach, was clearly depicted by plastination [21]. In addition, the blood supply of the proximal ulna, whose understanding is important to avoid fracture nonunion and the performance of elbow arthroplasty, was adequately shown by plastination [17]. This method was also proved precious in demonstrating the vascularization of metatarsals and the analysis of postoperative arterial damage, which are helpful in the preoperative planning of foot surgeries [23]. Bernal-Mañas et al. [4] showed that plastination revealed details of the anatomy of the lateral pterygoid muscle, which are valuable to temporomandibular joint surgery and joint degeneration. Thus, plastinated specimens are clinically important educational tools. The importance of the use of plastination in anatomy teaching needs to be further investigated about its educational effectiveness.

Limitations

The present study has limitations. The heterogeneity of the results did not allow the performance of a systematic review. If a higher number of papers had been included and statistical analysis had taken place, safer conclusions could be excluded.

Conclusion

The existing evidence about the outcomes of the use of plastination in anatomy education is relatively limited. Most studies evaluated students' perceptions and did not assess the impact of plastinated specimens' use on acquisition of knowledge and performance in anatomy examinations. There is a lack of comparative studies concerning the outcomes of plastinates vs fresh frozen cadavers or other anatomy teaching methods. However, the majority of papers of the current review showed that students reacted positively to the implementation of plastination concerning their learning experience, although it was not demonstrated that this method is superior to traditional cadavers dissection.

Author contributions DC and MP designed and wrote the paper. They equally contributed to the study. EOJ edited the paper. GT and AM

collected the data. GCB, VSN and KK contributed to the discussion of the data. KN edited and finally revised the paper.

Funding None.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Not applicable.

References

1. Abou Hashem Y, Dayal M, Savanah S, Štrkalj G (2015) The application of 3D printing in anatomy education. Med Educ Online 20:10
2. Azu OO, Peter AI, Etuknwa BT, Ekandem GJ (2012) The awareness of medical students in Nigerian Universities about the use of plastinated specimens for anatomical studies. Maced J Med Sci 5(1):5–9
3. Baker EW, Slott PA, Terracio L, Cunningham EP (2013) An innovative method for teaching anatomy in the predoctoral dental curriculum. J Dent Educ 77(11):1498–1507
4. Bernal-Mañas CM, González-Sequeros O, Moreno-Cascales M, Sarria-Cabrera R, Latorre-Reviriego RM (2016) New anatomoradiological findings of the lateral pterygoid muscle. Surg Radiol Anat 38(9):1033–1043
5. Bhandari K, Acharya S, Srivastava AK, Kumari R, Nimmagada HK (2016) Plastination: a new model of teaching anatomy. Int J Anat Res 4(3):2626–2629
6. Brenner E, Maurer H, Moriggl B, Pomaroli A (2003) General educational objectives matched by the educational method of a dissection lab. Ann Anat 185(173):229–230
7. Cook P (1997) Sheet plastination as a clinically based teaching aid at the University of Auckland. Acta Anat 158:33–36
8. Dhanwate AD, Gaikwad MD (2015) Plastination—a boon to medical teaching & research. Int J Sci Res 4(5):1550–1553
9. Estai M, Bunt S (2016) Best teaching practices in anatomy education: a critical review. Ann Anat 208:151–157
10. Fasel JH (1988) Use of plastinated specimens in surgical education and clinical practice. Clin Anat 1:197–203
11. Fruhstorfer BH, Palmer J, Brydges S, Abrahams PH (2011) The use of plastinated prosections for teaching anatomy—the view of medical students on the value of this learning resource. Clin Anat 24(2):246–252
12. Hammick M (2000) Interprofessional education: evidence from the past to guide the future. Med Teach 22(5):461–467
13. Haque ATME, Haque M, Than M, Khassan LHBM, Ishak AMB, Azmi ADBN, Rezal MADB (2017) Perception on the use of plastinated specimen in anatomy learning among preclinical medical students of UNIKL RCMP, Malaysia. J Glob Pharm Technol 9(9):25–33
14. Jadhav A, Kulkarni PR, Chakre G (2016) Plastination: a novel way of preserving tissues. Al Ameen J Med Sci 9(4):212–214
15. Jones DG, Whitaker MI (2009) Engaging with plastination and the Body Worlds phenomenon: a cultural and intellectual challenge for anatomists. Clin Anat 22(6):770–776
16. Kirkpatrick DI (1967) Evaluation of training. In: Craig R, Mittel I (eds) Training and development handbook. McGraw Hill, New York, pp 87–112
17. Koslowsky TC, Berger V, Hopf JC, Müller LP (2015) Presentation of the vascular supply of the proximal ulna using a sequential plastination technique. Surg Radiol Anat 37(7):749–755
18. Latorre RM, García-Sanz MP, Moreno M, Hernández F, Gil F, López O, Ayala MD, Ramírez G, Vázquez JM, Arencibia A, Henry RW (2007) How useful is plastination in learning anatomy? J Vet Med Educ 34(2):172–176
19. McRae KE, Davies GA, Easteal RA, Smith GN (2015) Creation of plastinated placentas as a novel teaching resource for medical education in obstetrics and gynaecology. Placenta 36(9):1045–1051
20. Neha Lalwani S, Dhingra RJ (2013) Plastinated knee specimens: a novel educational tool. Clin Diagn Res 7(1):1–5
21. Oppermann J, Franzen J, Spies C, Faymonville C, Knifka J, Stein G, Bredow J (2014) The microvascular anatomy of the talus: a plastination study on the influence of total ankle replacement. Surg Radiol Anat 36(5):487–494
22. Papa V, Vaccarezza M (2013) Teaching anatomy in the XXI century: new aspects and pitfalls. Sci World J 2013:310348
23. Rath B, Notermans HP, Franzen J, Knifka J, Walpert J, Frank D, Koebke J (2009) The microvascular anatomy of the metatarsal bones: a plastination study. Surg Radiol Anat 31(4):271–277
24. Riederer BM (2014) Plastination and its importance in teaching anatomy. Critical points for long-term preservation of human tissue. J Anat 224(3):309–315
25. Sora MC, Jilavu R, Matusz P (2012) Computer aided three-dimensional reconstruction and modeling of the pelvis, by using plastinated cross sections, as a powerful tool for morphological investigations. Surg Radiol Anat 34(8):731–736
26. Von Hagens G, Tiedemann K, Kriz W (1987) The current potential of plastination. Anat Embryol 175:411–421