DISSERTATION

Effects of the course "Clinical Anatomical Imaging of the Head for Dental Students" as part of preclinical anatomy education on student performance and motivation

Auswirkungen des Kurses „Klinisch-anatomische Bildgebung des Kopfes für Zahnmedizinstudierende“ auf Leistung und Motivation im vorklinischen Anatomieunterricht

zur Erlangung des akademischen Grades
Doctor medicinae dentariae (Dr. med. dent.)

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List of Abbreviations

CBCT	Cone beam computed tomography
CBL	Computer-based learning
CI	Confidence interval
CT	Computed tomography
ID	Instructional design
ILO’s	Intended learning outcomes
IQR	Interquartile range
MCQ	Multiple choice questions
MIRC	Medical Imaging Resource Centre
MRI	Magnetic resonance imaging
n	Sample size
OPG	Panoramic radiograph
p	p-value
PBL	Problem-based learning
r	Pearson’s correlation coefficient
SD	Standard deviation
SEM	Standard error of the mean
TU	Teaching unit
UbD	“Understanding by design” (Wiggins and McTighe, 2005)

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Zusammenfassung

Einleitung: Obwohl Anatomie nach wie vor eines der zentralen vorklinischen Fächer darstellt, werden die vorklinischen Lehrpläne zunehmend mit anderen Grundlagenfächern gefüllt, wodurch die Unterrichtszeit für anatomische Inhalte stetig abgenommen hat. Dozierende sind besorgt über den Rückgang der anatomischen Kenntnisse, und es wird deutlich, dass der Anatomieunterricht an die Veränderungen in der Lehre angepasst werden muss. Das Präparieren von Körperspenden bleibt an den meisten Universitäten die meistverbreitete Lehrmethode, aber viele appellieren, dass die Integration von Bildgebung ein großes Potenzial bietet, um das Interesse von Studierenden zu steigern und das Verständnis zu vertiefen. Während sich die derzeitige Forschung überwiegend auf Medizinstudierende konzentriert, hat sich diese Studie auf die Untersuchung der Auswirkungen dieses integrierten Lehransatzes auf die Leistung und Motivation von Zahnmedizinstudierenden konzentriert.

Methodik: Das dritte vorklinische Semester wurde in eine Kontroll- und eine Interventionsgruppe unterteilt. Es wurde ein Lehrplan konzipiert, der der Interventionsgruppe parallel zu ihrem Präparierkurs vermittelt wurde. Der Lehrplan wurde nach der Methode des Backward Design von Wiggins und McTighe erstellt. Um die Auswirkungen des Kurses auf die Motivation zu analysieren, wurde eine Umfrage am Ende des Kurses an die Interventionsgruppe verteilt. Um die Auswirkungen auf die Leistung zu bewerten, wurde ein Prüfungsformular erstellt, das drei Stufen der Bloom'schen Taxonomie verwendet und am Ende des Kurses sowohl der Interventions- als auch der Kontrollgruppe zum Vergleich vorgelegt wurde. Die wichtigsten deskriptiven Statistiken wurden angewandt, um die Antworten in der Studierendenbefragung zu analysieren, und es folgte ein Hypothesentest mit einer unabhängigen Stichprobe mit zwei gepaarten t-Tests, um signifikante Veränderungen in der Leistung nach der Teilnahme am integrierten Ansatz zu bewerten.

Ergebnisse: Die Studierenden zeigten sich sehr zufrieden und hielten es insgesamt für vorteilhaft für ihre Ausbildung. Sie erkannten, dass der integrierte Ansatz zu einem höheren Wissensstand in der makroskopischen Anatomie und Radiologie führte. Wenn auch nicht statistisch signifikant, so wurde doch ein positiver Einfluss auf die Leistungen der Studierenden festgestellt, insbesondere in den unteren Bereichen der kognitiven Anforderungen.

Schlussfolgerungen: Ein integrierter Ansatz für die anatomisch-radiologische Lehre ist eine effiziente und kostenwirksame Möglichkeit, die durch den Mangel an Unterrichtszeit entstandene Lücke zu schließen und gleichzeitig die Anatomiekenntnisse der Studierenden zu verbessern und ihr Interesse zu fördern.

Abstract

Introduction: Preclinical curricula in medical education are increasingly overflowing with other basic sciences, and while anatomy remains a central subject, its instructional time has seen a steady decrease. Educators are concerned about declining levels of anatomical knowledge, and it has become clear: the instruction of anatomy must adapt to contemporary teaching and curricula changes. Cadaveric dissection prevails as the main instructional method in most universities, but how to make this method more efficient? Many agree to see great potential in integrating radiographic imaging to increase interest, and deeper understanding of anatomy. While the current body of research has mostly focused on medical students, this study has focused on studying the effects of this integrated teaching approach on the performance and motivation of dentistry students.

Methods: The third preclinical semester was divided into a control and an intervention group. A curriculum was conceptualized and was delivered to students of the intervention group in parallel with their dissection course. The curriculum was written utilizing the backwards design method by Wiggins and McTighe. To analyse the courses' effect on student motivation, a survey was designed and handed out at the end of the course to the intervention group. To assess the effects on student performance, an assessment form was created utilizing three levels of Bloom's taxonomy and delivered at the end of the course to both the intervention and control group for comparison. Key descriptive statistics were applied to analyse responses in the student survey and hypothesis testing followed, with an independent samples two paired t-test to assess significant changes in performance after attending the integrated approach.

Results: Students reported high levels of satisfaction and thought it to be altogether advantageous for their education. They recognized the integrated approach for an increased level of knowledge in gross anatomy and radiology. Though not statistically significant, a positive impact on student performance was observed, especially in lower domains of cognitive demand.

Conclusions: An integrated approach of teaching anatomy with radiology is a resourceful and cost-effective way to address the gap created by the shortage of instruction time, while improving students' knowledge of anatomy and boosting their interest levels.

1. Introduction

1.1 Anatomy in medical education

1.1.1 Traditional approaches and modern trends

Anatomy has persistently played a central role in the medical curriculum (Drake et al., 2009, Estai and Bunt, 2016). For centuries, the practical teaching and learning of anatomy has heavily relied on the utilization of cadaveric dissection, as it was customarily endorsed as the most effective method of instruction for the subject (Moxham and Plaisant, 2014, McLachlan and Patten, 2006).

However, with the emergence of other basic science disciplines, like biochemistry or physiology, that take up most of the undergraduate curricula, there has been a substantial decrease in the instruction of anatomy in medical courses (Tibrewal, 2006, Collins et al., 1994, Drake et al., 2009).

As a repercussion of these changes, there has been a notable reduction in dissection (Tibrewal, 2006) that could be explained by the deficit of allotted time for anatomical instruction, given that dissection is a time-costly form of instruction. Also, there being less cadavers made available for instruction and the fast-growing numbers of enrolled medical students (Collins, 2009, Pryde and Black, 2005) seem to play a role in this decrease.

In contemporary teaching, a trend has become clear: the traditional undergraduate anatomy curriculum has been rearranged into a more student-centered learning concept. This entails an addition of system-based strategies, specialized and practically applied curricula (Tibrewal, 2006), as well as the development of integrated approaches (Azer and Eizenberg, 2007, Drake et al., 2009). As Azer and Eizenberg describe, this mainly consists of presenting the anatomical curriculum through a problem-based learning (PBL) approach or case-based instructions (Azer and Eizenberg, 2007).

These trends have been made visible through studies; for example, Tibrewal determined that as a result of this deficit of instruction, consultant surgeons in the UK believed that the degree of knowledge and skills in medical students has significantly declined over the past decade (Tibrewal, 2006). The decline of anatomical knowledge amongst students is a frequent concern (Collins, 2009, Older, 2004, Pryde and Black, 2005), and the knowledge levels are even considered inadequate and below expected by some (Lockwood and Roberts, 2007, Prince et al., 2005, Older, 2004, Brunk et al., 2017).

Collins summarizes the challenges in teaching and learning anatomy as follows (Collins, 2009):

- Reduced teaching time
- Fewer tutors
- Increasing student numbers
- Diversity amongst students
- Changes in the anatomy curriculum
- Adjustment from teacher-centred to student-centred learning
- Lack of empirically tested evidence related to the assimilation and application of the knowledge of anatomy

A central discussion about the future of anatomy education revolves around the effectiveness of cadaveric dissection as the primary teaching method, questioning whether it has become outdated and should be eliminated from medical curricula, or if its role in teaching anatomy should just be limited and replaced by other methods (Azer and Eizenberg, 2007, Bergman, 2015, Onigbinde et al., 2021, Estai and Bunt, 2016).

Demands and available resources for anatomy education are evidently evolving, and so curriculum writers and instructors are faced with the question: How to best teach anatomy in the present day?

1.1.2 Contemporary teaching methods

Brenner et al. described six categories of teaching tools, offering an array of approaches to anatomy instruction (Brenner et al., 2003):

- dissection by students,
- inspection of prosected specimens,
- didactic teaching,
- use of models,
- computer-based learning (CBL), and
- teaching of living and radiological anatomy (Brenner et al., 2003)

While Patel and Moxham reported that professional anatomists are receptive towards curriculum changes, there remains a consensus that dissection is the most effective teaching method, closely followed by prosection (Patel and Moxham, 2005).

As universities attempt to optimize their teaching methods, several questions arise: How do these approaches differ from each other? What are their respective advantages and disadvantages? What method better fits the institution and course? These questions may not yet have definitive answers, as it seems that many universities have opted to blend these distinct teaching approaches in the hope of optimizing their instruction (Heylings, 2002).

During dissection classes, students, usually guided by a tutor, examine anatomical structures of the human body by cutting and separating tissues and layers. They perform dissection on human cadavers, which results in students engaging with actual deceased patients, and this encounter is believed to serve as the initial tool for instilling medical professionalism and for the development of stress management skills as well as empathy amongst future professionals (Böckers et al., 2010). This task is said to foster a higher understanding of the human body's three-dimensional structure (Collins, 2008). It also closely replicates the activities of surgeons, leading some to propose that only a specific cohort, namely, those aspiring to work in the surgical field, may actually require this type of training (Leung et al., 2006, Collins, 2008).

For an enhanced student learning experience during dissection classes, various tools can be employed, including models, imaging, and CBL (Steinborn et al., 2021). The considerable expenses tied to the upkeep of mortuaries and laboratories, the health risks associated with exposure to formalin fumes, and psychological challenges as well as the high time consumption involved are the main reasons for wanting to reduce and discontinue dissection as a form of instruction (McLachlan and Patten, 2006, Aziz et al., 2002).

As the time available for anatomy instruction diminishes, many institutions have chosen to substitute dissection courses with the examination of prosected specimens (Dinsmore et al., 1999), which are essentially pre-dissected cadavers (Collins, 2008). This teaching method enables students to efficiently observe anatomical structures and their interrelationships. Furthermore, this approach reduces the demand for cadavers, as a single prosected specimen can be shared by multiple students (Dinsmore et al., 1999, Collins, 2008). Yeager revealed that between students who learned anatomy through dissection and those who studied it by examining prosected cadavers, there was no substantial variation in learning outcomes (Yeager, 1996).

Anatomical models are used to present physiological anatomy to students; however, their usage was valued as the least effective way to instruct gross anatomy (Patel and Moxham, 2005). Students face greater obstacles when working with human cadavers compared to anatomical models, and thus the former cannot be regarded as an equivalent preparation for future professional roles (Steinborn, 2019). However, they could be used complementarily, to for instance, elucidate complex spatial relationships (Steinborn et al., 2021).

While didactic teaching in the form of lectures has traditionally always played a certain role in instruction, the curriculum is changing towards a more blended approach of teaching, reducing pure lecture-style instruction. This, however, relies heavily on students studying the teaching material outside of class, which increases their workload (Estai and Bunt, 2016).

Computer-based learning (CBL) refers to any kind of computer-assisted learning. With technological advancements and changes in curriculum, CBL has increased in popularity. While some research suggests that students may lean toward traditional methods over CBL (Azer and Eizenberg, 2007), other studies have reported the highly positive evaluations of students towards technological tools, such as software for visualizing anatomy (Steinborn et al., 2022). Nonetheless, it appears that CBL would be more effective as a supplementary tool rather than a standalone method for teaching anatomy (Tam et al., 2010, Steinborn et al., 2022).

Living anatomy describes the study of the subject through living individuals. A classic approach to this involves peer physical examination, where students inspect and even perform examinations on each other, such as ultrasounds (Rees et al., 2004), offering an initial exposure to clinical inspections (Patten, 2007). While it complements the learning of anatomy and engages students, it might not serve as a replacement for other approaches.

Collins calls attention to the significance of incorporating radiographic images into anatomy education, as such integration not only facilitates the connection to clinical context but also enhances student interest and motivation by aligning practical skills for their future careers (Collins, 2009). It is considered by some as “the modern equivalent of traditional anatomical dissection” (Collins, 2008), as three-dimensional imaging can be used to go through slices of a scan like one would dissect layers on a human cadaver.

The study at hand delves into the integration of radiology into preclinical dissection courses, and thus, this modern anatomy teaching approach will be discussed in depth in subsection 1.3.

Suggestions towards the effective teaching of anatomy made by Collins revolve around utilizing a combination of prosection, living-anatomy and radiology (Collins, 2008). Recommendations were also made towards promoting the application of anatomical knowledge in a clinically relevant context (Brunk et al., 2017) and thus a bigger integration of anatomy teaching with other subjects.

However, within the field of anatomy education, clarity and consensus remain lacking. The current body of research does not provide a clear preference for any approach in the teaching, learning, and assessment of anatomy. Moreover, studies examining the recall and practical application of anatomical knowledge are insufficient in number, and these studies often lack a rigorous scientific methodology (Winkelmann, 2007, McLachlan and Patten, 2006). The argument that current graduates exhibit a lower degree of anatomical knowledge is also disputed (Collins, 2008).

To resolve this ongoing discussion, future research should aim to provide evidence to guide educators and curriculum makers through the choice of different teaching methods. In the absence of clear answers, one must carefully consider the appropriateness of further diminishing instructional time of anatomy education when creating and reinventing medical curricula (Brunk et al., 2017).

1.1.3 Anatomical curriculum of the dentistry degree at Charité

The examination and licensing regulations for dentists in Germany from 1955 remained unaltered for more than 60 years and delineated the following anatomical curriculum:

In the preclinical phase of their studies, which spans from the first to the fifth semester, students are instructed in macroscopic and microscopic anatomy. Both these subjects are taught in two distinct courses.

The teaching of macroscopic anatomy is further divided into a lecture series and a dissection course, the ratio of instructional hours for each being 4:3, respectively. The intended learning outcomes are the in depth understanding of macroscopic anatomy of areas like, but not limited to, the head and neck region, the nervous system, the sensory organs, and other body cavities.

Microscopic anatomy is also taught by means of lectures and practical exercises with a microscope. Instruction of this subfield of anatomy is done within a much-reduced time limit. Students that have completed these modules can describe the organization of cells and histological tissues pertaining to organs and structures within the oral, nasal, neck, thoracic, abdominal, and pelvic regions (with the exemption of the reproductive system), as well as the central nervous system and the sensory organs.

A summarized overview of the learning contents for each preclinical semester in both macroscopic and microscopic anatomy can be found in Table 1:

Table 1 Overview of the anatomical curriculum at Charité in place until the winter semester of 2021 (old licensing regulations) – University Medicine Berlin.

Semester	Macroscopic Anatomy	Microscopic Anatomy
1	• General Anatomy • Anatomy of the Skull **Exams**: "General Anatomy" and "Osteology"	No instruction in the first semester
2	• Systematic and functional anatomy of the thorax, abdomen and the retroperitoneal space **Exam**: "Anatomy of the thorax, abdomen and the retroperitoneal space"	• Cytology, general microscopic anatomy • Organ histology **Exams**: "General Histology" and "Histology of Internal Organs"
3	• Head and Neck Anatomy **Exams**: "Neck Anatomy and superficial structures of the Head" and "Deep structures of the Head"	• Organ histology (continuation, focus on head and neck organs, excluding Neuroanatomy) • Histology of the oral cavity **Exam**: "Histology of the organs and of the oral cavity"
4	• Systematic and functional anatomy and topography of the central nervous system, cranial nerves and sensory organs **Exam**: "Neuroanatomy"	• Neurohistology **Exam**: "Neurohistology"

5	Consolidation of all the taught content listed above **Exam**: “Topographical anatomy of the head and neck”	Consolidation of all the taught content listed above **Exam**: none

This course was conceptualized while the “old” regulations were still in place; however new licensing regulations for dentists in Germany came into effect in July of 2019 and were practically adopted with the new class of the winter semester 2021/2022 (Berlin, 2021, Uzun et al., 2023), and the cohort of this project have already studied dentistry with the new curriculum changes in place. The major differences to the old regulations pertaining to anatomical education are that the preclinical phase of the degree was shortened from 4 to 5 semesters, shortening anatomy instruction by half a year. Notably, the skull bones, which were taught in the first semester, have now been moved to the third preclinical semester.

1.2 Radiology in medical education

1.2.1 Traditional approaches and evolving trends in radiology education

Radiological education mainly relies on traditional lecture-style teaching, along with case-study seminars and practical sessions to provide knowledge transfer and application (Slanetz et al., 2013, Jarrett-Thelwell et al., 2019). The most common way to allow students to gain direct contact with radiological departments and exposure to clinical tasks within this subject is through clerkships during clinical years (Radiology, 2011). Regarding this traditional teaching style, there is a relative consensus that a blended, more interactive, and integrated approach is effective and necessary (David Howlett, 2011, Kitt Shaffer, 2004, Jarrett-Thelwell et al., 2019, O'Connor et al., 2016). It is worth noting that in Europe, already 32% of medical universities already adhere to a “hybrid approach” incorporating radiology into other clinical modules (Radiology, 2011).

The modern world is increasingly digitalised, and thus healthcare systems, especially in fields like radiology, make use of technological devices to produce and view imaging. Many researchers defend the potential of incorporating e-learning methods into radiology learning (Kitt Shaffer, 2004, Saad Zafar, 2014, David Howlett, 2011, Webb and Choi, 2014). This support is already being reflected in practice, as shown in a report by the

European Society of Radiology, which indicated that 74% of universities have e-learning resources accessible to their students (Radiology, 2011).

Students may find radiology more appealing when they recognize its potential relevance to their studies and future. This underscores the importance of aligning the radiology curriculum within the full educational framework of medical students, effectively using it towards improving comprehension of other subjects, such as anatomy and pathology (Radiology, 2011).

Even though most universities only expose students to radiology in the final years of their studies (Radiology, 2011), the call for an earlier exposure is present, as seen in institutions following a modern curriculum that brings radiology into preclinical years (Oris et al., 2012). When introduced to radiology in the first year of their studies, students expressed a greater interest for the subject overall upon graduation (Barton F. Branstetter, 2008), accentuating the benefits of early exposure.

Mirsadraee et al. analysed the perspectives of experts with diverse backgrounds in medical education on this topic. Their survey revealed that 95.2% of experts were in favour of including radiology within anatomy in the undergraduate curriculum. Furthermore, 90.5% supported the integration of radiology teaching within anatomy dissection (Mirsadraee et al., 2012).

1.2.2 The importance of radiology in dental practice

Dentists rely extensively on radiographs, often referred to as the primary diagnostic tool for dental professionals (Whaites and Drage, 2021). Radiographic assessments are an essential part of dental practice as they are required for nearly every patient (Whaites and Drage, 2021) and are pertinent towards developing precise treatment plans.

Radiology within the dental context primarily examines oral and maxillofacial structures, playing a critical role in diagnosing and planning within oral healthcare (Whaites and Drage, 2021). Its usage as a diagnostic tool allows for the detection of a range of conditions, including cavities, periodontal diseases, orthodontic requirements, implant dentistry, and trauma handling (Whaites and Drage, 2021).

Specialized techniques are necessary in dental radiology to capture high-quality images of teeth and jaws. These techniques, such as panoramic radiography (OPG) (as seen in Figure 1) (Molander, 1996) and cone beam computed tomography (CBCT) (depicted in

Figure 2) (Shukla et al., 2017), are distinct from techniques used in general medical radiology. The specialised approach in dental radiography ensures the detailed examination of oral and maxillofacial structures.

In summary, one could argue that dentists, while not specializing in radiology, are inherently involved in the subject. This differs from medical doctors, which other than the ones pursuing or working in the speciality, may have very little daily contact to the subject.

Figure 1 Normal OPG. Panoramic radiography. (Hacking, 2015)

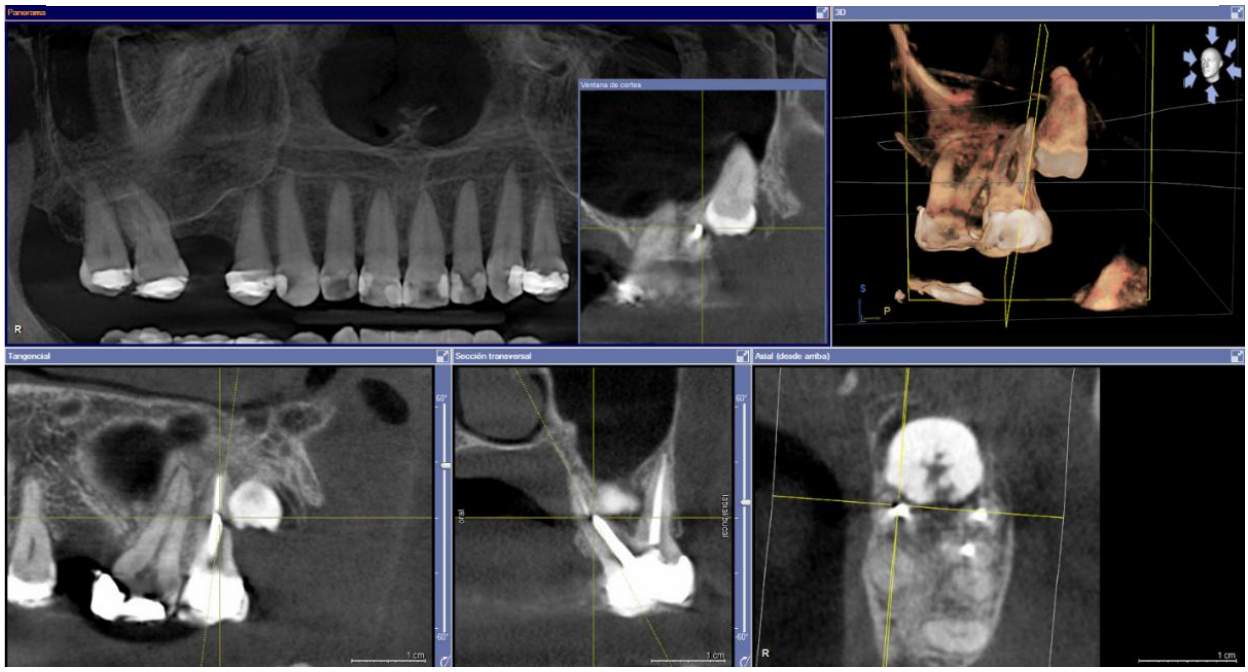

Figure 2 External dental root resorption. Parasagittal, coronal and axial views. CBCT. (Uribe, 2016)

1.2.3 Radiology curriculum of the dentistry degree at Charité

At Charité's dentistry faculty, the study of radiology is introduced into the dental curriculum during the sixth semester (Berlin, 2021), meaning that there is no overlap between the teaching of anatomy and radiology within the dental program. The specific module is titled 'Radiological course with special consideration of radiation protection,' emphasizing its focus on educating students about current radiation protection laws, regulations, and relevant guidelines.

The subjects addressed in this module encompass, but are not restricted to:

- Understanding and applying various methods relevant to dental radiography, and their appropriate usage
- Distinguishing normal and abnormal radiological findings in dental and adjacent anatomy
- Comprehending radiation protection, equipment, and quality assurance in dental radiography

Instruction is delivered through a lecture series, a practical using a phantom head mannequin, and a practical in the radiology department with real patients in treatment at the institution's clinic.

1.3 Integration of radiology in anatomy education

1.3.1 Potential benefits resulting from an integrated approach

Historically, radiology only facilitated anatomy teaching on the level of skeletal anatomy through plain radiography (Gunderman and Wilson, 2005). These images, while valuable, have limitations, particularly in visualizing soft tissues due to overlapping structures in a single plane (Gunderman and Wilson, 2005). Anatomy education made better usage of imaging following the emergence of ultrasound, CT, and MRI. These advancements allowed for comprehensive depictions of anatomy in both two and three dimensions, so that today, medical imaging offers exceedingly detailed images of internal human anatomy and can be used for student learning (Gunderman and Wilson, 2005).

As mentioned earlier, studies have shown that students frequently have inadequate anatomical knowledge when they finish medical school, despite having demonstrated competence in this area during preclinical studies (Cottam, 1999, Feigin et al., 2007). This shortfall is particularly notable, as it is precisely during this phase that they are expected

to apply their anatomical understanding in a clinical context, where the interpretation of medical imaging also becomes crucial for non-radiologists (Orsbon et al., 2014). Hence, a preclinical radiology curriculum could serve a dual role, not only in teaching radiological principles and simulating interest but also potentially enhancing the long-term retention of radiographic knowledge through repeated exposure (Feigin et al., 2007).

Researchers were already advocating for integrative anatomy teaching over 35 years ago (Pabst et al., 1986). While still asserting that small group cadaver dissection should stand at the centre of anatomy education, Pabst et al. found that enhanced clinical teaching (through means of integrating living and radiological anatomy, as well as case presentations) elevated student engagement in dissection. For these researchers, it became evident that a clinically oriented gross anatomy curriculum was very well-received by participating students (Pabst et al., 1986).

When integrated into dissection courses, the use of medical images can enhance students' comprehension of spatial relationships among anatomical structures (Pabst et al., 1986). It also boosts their dissection efficiency and sparks greater interest in the subject (Pabst et al., 1986) by enabling the application of their anatomical knowledge, and by connecting it to clinical relevance with their scope of understanding (Lufler et al., 2010). Moreover, utilizing medical imaging for anatomy instruction offers a significant advantage – the ability to observe live anatomy (Gunderman and Wilson, 2005). Unlike the cadaver, which provides only postmortem, static anatomy, often differing from the premorbid state, radiological imaging studies typically involve living patients (Gunderman and Wilson, 2005). Also, radiological case studies can introduce students to a broader range of pathologies than is provided by a cadaver during dissection courses (Gunderman and Wilson, 2005).

While radiology provides a valuable method for teaching gross anatomy, it has notable limitations when used as the sole approach (Gunderman and Wilson, 2005, Aziz et al., 2002), hence, there has been encouragement for its integration with dissection in teaching (Aziz et al., 2002, Gunderman and Wilson, 2005, Howe et al., 2004), providing a more effective approach to the study of gross anatomy.

While acknowledging the merits of integrating radiology with dissection, the upcoming section will delve into various approaches and examples to illustrate its effective implementation and the potential outcomes it can yield.

1.3.2 Examples of integrated approaches

In 2007, the Medical School of Hannover (MHH) launched the elective module “radiological anatomy” for second year medical students (Dettmer et al., 2013). This elective module combined preclinical education with radiology, where students interpreted radiological images and solved clinical cases. At the end of the course, students' knowledge was assessed through an exam that included both essay questions and radiological images, and grading was based on this outcome as well as in-class participation.

Dettmer et al. surveyed student perspectives on the elective module, revealing that approximately 90% of students agreed that the integration of radiology improved their comprehension of anatomy (Dettmer et al., 2013). They attributed this to improved spatial awareness gained from using radiological images. Additionally, 93% of students acknowledged the practical value of their newly acquired knowledge for their future careers. Notably, students who participated in this elective course showed slightly better performance in subsequent radiology exams during their fifth year, compared to those who did not take the elective.

Murakami et al. also determined that the inclusion of radiology in early anatomical courses led to enhanced radiology skills in later clinical courses (Murakami et al., 2014). Their teaching system combined anatomical dissection with diagnostic CT radiology. Through this approach, cadavers underwent CT scans, and students used postmortem CT images during dissection classes to help them understand 3D anatomy and diagnostic radiology. Students also participated in lectures, workshops on diagnostic radiology, and study assignments that compared anatomy lab findings with CT radiology results. This approach, which was implemented in 2009, garnered positive student feedback and led to improved radiology skills in subsequent clinical courses (Murakami et al., 2014).

While these studies investigate student satisfaction with this teaching approach, they do not examine its impact on student performance in anatomical tests, which could allow for the measurement of knowledge acquisition. Chew et al. conducted a study that directly correlated integrated teaching with improved test outcomes in anatomy. However, this study did not assess student satisfaction and their observations (Chew et al., 2020).

At the university of Glasgow, radiology small group instruction was integrated into the anatomy curriculum for first-year medical students in the academic years 2016/17 and

2017/18 (Chew et al., 2020). In the first year of the curriculum, there is an initial "Introduction to Anatomy" (Phase 1), followed by “Anatomy of the Limbs and Back" and "Anatomy of the Cardiovascular and Respiratory Systems “(Phase 2). Phase 2 involves laboratory work, consisting of both "wet" cadaveric dissection and "dry" examination of prosected specimens, each lasting 90 minutes. In the academic years 2016/17 and 2017/18, a trial period incorporated radiology into Phase 2's "dry" laboratory sessions through brief didactic lectures and interactive radiology stations.

This involved a concise 10-minute lecture on relevant Radiologic Anatomy, followed by small groups rotating through a radiology station where students viewed radiologic images depicting common clinical scenarios related to the week's region of interest.

First-year students take summative end-of-year examinations where anatomy is a significant component, assessed through multiple-choice questions (MCQ). An analysis of examination papers and scores from the 2015–2019 academic years by Chew et al. (2020) demonstrated that small group radiology instruction significantly improved first-year students' anatomy MCQ scores during the end-of-year examination.

Another approach to achieve this type of integration involves utilising innovative technological tools, allowing the exploration of how these resources can be employed towards enhancing the learning experience.

A learning tool, known as radiological anatomy eLearning, was developed for the first year at the University of Southampton's Faculty of Medicine (Webb and Choi, 2014). This tool involved various activities for students, focusing on identification and learning from both typical and abnormal X-ray images. Its effectiveness was assessed through questionnaires, pre- and post-tests, focus groups, summative assessments, and data tracking.

Webb and Choi concluded that students had a positive experience with the eLearning tool, with 77% enjoying the learning process (Webb and Choi, 2014). Additionally, 80% of students found the eLearning tool beneficial for their anatomy revision, and 69% acknowledged it aiding them to apply anatomical knowledge in clinical contexts. After the final assessment, students exhibited significantly better knowledge in eLearning-related topics compared to those not covered by the tool.

Similarly, Marker et al. utilized modern technology for this integration (Marker et al., 2010). A set of digital teaching images were gathered and structured to match the subjects covered in lectures and dissection. The Medical Imaging Resource Centre (MIRC) was utilized to deliver these images through a web-based format, integrating them into anatomy lectures in hopes of facilitating review of anatomical material. These lectures encouraged active participation, with interactive discussions between medical students and the presenter regarding the labelled images. To assess the effectiveness of this educational approach, a survey was conducted of medical students. The results indicated that 87% of the respondents found the MIRC teaching files valuable, rating them from "somewhat useful" to "very useful" when incorporated into the lectures.

When researching the previously studied effects of integrated curricula on dental student cohorts, one finds that the evidence for investigated effects of several integrated curricula based on PBL approaches have been investigated (Aung et al., 2016, Last et al., 2001, Fincham and Shuler, 2001, Rowland and Joy, 2015, Abdalla, 2020), with studies reporting favourable outcomes in student satisfaction and either an improvement in performance on anatomical tests, or at minimum, unchanged results. These integrations were not focused on radiology, and the studies conducted with that focus were only found to be more narrowly restricted to dental anatomy.

An example would be the utilization of radiographs, CBCT Scans and virtual reality to help visualize root canal anatomy (Reymus et al., 2020) within the endodontics curriculum, which was deemed as a successful learning method by students. Nair et al. integrated radiographs and oral pathologies into oral anatomy teaching and showed that students performed better under this approach (Nair et al., 2020). Integrated approaches with radiology for the general anatomical education of dental students were not found.

1.3.3 Foundational measures for successful integration

Effective integration, as highlighted by Heptonstall et al., predominantly occurs when radiology is seamlessly integrated into dissection courses (Heptonstall et al., 2016). However, it is important to note that dedicated radiology teaching is necessary to ensure that students acquire basic knowledge in image interpretation principles (Heptonstall et al., 2016).

Besides classroom instruction, there is a case to be made about self-directed learning, as it offers a cost-efficient learning approach, as demonstrated by Phillips et al. (2013).

When exploring the preferred teaching methods for radiological anatomy, Mirsadraee et al. showed a consensus amongst experts, demonstrating the significance of cross-sectional imaging techniques, such as CT and MRI, for this purpose (Mirsadraee et al., 2012). Plain radiographs also received positive feedback, with a remarkable 97.6% agreement among experts of their usefulness, while ultrasound and nuclear imaging were not as highly endorsed.

This section concludes by emphasizing the importance of a multifaceted approach to integrating radiology effectively within anatomy education. A seamless integration into dissection courses, along with a dedicated unit or time allocation for radiology teaching, can benefit student learning for both subjects.

1.4 Research Question and Objectives

1.4.1 Motivation and procedure

Existing research underscores a significant concern regarding the extent of anatomical knowledge among students, an issue that has been consistently observed, with studies often revealing a lack of knowledge. Simultaneously, the field of anatomy education is undergoing a transformation brought about by changes in preclinical curricula, and when considering teaching approaches going forward, a lack of consensus and clear guidance on the most effective teaching methods for current educational practice remains.

Central to this transformation lies the question of the role of dissection courses as the primary approach for instruction of gross anatomy. When considering alternatives, many options present themselves, and research has not only reinforced the value of applying anatomical knowledge to clinical contexts as a way of improving student engagement and interest, but simultaneously for encouraging an array of integrated teaching approaches.

The integration of gross anatomy education with radiology is particularly noteworthy, and this has gained considerable attention. This approach aligns with the wider call for the incorporation of radiology education into preclinical curricula, providing valuable support for the comprehension of various subjects, including anatomy.

Experts have endorsed the integration of radiology into undergraduate anatomy curricula, specifically within the framework of dissection courses. This approach might have the potential to enhance students' grasp of spatial relationships and stimulating their

enthusiasm for the subject. Furthermore, it achieves the vital objective of linking the content of anatomy instruction with clinical relevance.

To the best of our knowledge, there has been an absence of research examining the impact of integrating radiology into the preclinical gross anatomy education of dentistry students. Although numerous studies have concentrated on medical students, we argue that the importance of investigating this effect within dental education is critical, considering that dentistry is a specialty with heavy radiological involvement.

This prompted our question as to the potential benefits that dentistry students might gain from curriculum modifications within preclinical anatomy education. To investigate this, we opted to incorporate a radiology course into the curriculum during the third preclinical semester, which is dedicated to the study of head and neck anatomy. We believe that this integration will yield the most favourable outcomes, as it aligns with the specific needs of dentists, whose work relies heavily on a comprehensive understanding of head and neck anatomy, primarily in their later careers.

This study comprises a conceptual course, titled "Clinical Anatomical Imaging of the Head for Dental Students", which was incorporated into the standing anatomical curriculum. This course began with a dedicated unit aimed at providing students with foundational knowledge in radiology. Subsequently, it established connections between the anatomical structures under dissection and their corresponding radiological presentations and linked this to clinical relevance by presenting cases. The imaging methods that were introduced were plain and dental radiographs, computed tomography (CT) and magnetic resonance imaging (MRI). Ultrasound and nuclear medicine were excluded.

To assess the effectiveness of this integration, a controlled experiment took place. Approximately one-third of the students were offered the modified curriculum, while the rest followed the conventional curriculum, thus establishing distinct control and intervention groups. A student assessment form was handed out, which was a quiz based on the dissection course content and accompanying lectures. The purpose was to evaluate the impact of this integration on student performance concerning anatomy-related questions, without incorporating any radiology course material into the assessment.

Furthermore, to gain students' perceptions and insights, a survey was developed and exclusively administered to the intervention group. Through this study, we aim to draw

definitive conclusions regarding the potential of an integrated approach in preclinical anatomy education with radiology for dentistry students. The goal is to understand whether this approach indeed enhances students' anatomical knowledge, and to illuminate the extent to which it is well-received by the student body.

The process unfolded as follows:

1. The conceptualization of the integrated course.
2. The development of the student assessment form.
3. The creation of the student feedback survey.
4. The implementation of the course during two consecutive semesters.
5. The collection and analysis of the data.

1.4.2 Objectives

The central research question addressed in this dissertation is:

To study the effects of the conceptualized course "Clinical Anatomical Imaging of the Head for Dental Students" as part of preclinical anatomy education on the performance and motivation of dental students of the third preclinical semester at Charité-Universitätsmedizin Berlin, in comparison to students of the same semester that did not attend the course.

The main objectives were:

- To evaluate the effectiveness of integrating radiology in preclinical anatomy curriculum for dentistry students. For this, the impact of a conceptualized course called "Clinical Anatomical Imaging of the Head for Dental Students" on dental student performance in gross anatomy was assessed, by comparing the different outcomes in a student performance form, filled out by both the intervention and a control group.
- To assess participating students' perceptions of the integrated approach through a survey filled out by the intervention group.

The questions this study seeks to address include, but are not limited to the following:

- Does the integration of clinical cases increase students' enthusiasm for anatomy, and do they retain the different conditions and pathologies that are introduced?

- To what extent does the incorporation of 3D imaging enhance the comprehension of complex anatomical structures and their interrelationships within the head and neck region?
- How do students perceive this teaching approach, and what suggestions do they have for its improvement?
- How do they self-evaluate their gained knowledge through the course?
- Are there significant differences in the results of the student assessment between the control and intervention groups? Furthermore, do performance disparities exist when considering the various question types?

2. Methodology

2.1 Ethics Approval

The ethics committee of Charité - University Medicine Berlin approved the conduct of the study “Effects of the conceptualized course "Clinical Anatomical Imaging of the Head for Dental Students" as part of preclinical anatomy education on student performance and motivation” (ethics committee approval number: EA1/213/23).

2.2 Development of the conceptualized course "Clinical Anatomical Imaging of the Head for Dental Students" with the backwards design method

The instructional design (ID) for this course followed the backwards design method as explained in “Understanding by design” (UbD) (Wiggins and McTighe, 2005). Each of the three steps utilizes a unit template to guide instructional design (McTighe, 2023).

2.2.1 Disclaimers about the course conceptualization

As mentioned above, this study has been developed to focus on investigating whether incorporating radiology into preclinical anatomy classes could lead to improved student performance and motivation in macroscopic anatomy.

In this case, however, when evaluating the conceptualized course's goals and learning objectives, a contradiction appears. On one hand, when only considering the supplementary teaching material that was created, the Intended Learning Outcomes (ILO’s) are primarily radiological knowledge and skills, because radiology instruction is what was added to the standing anatomy curriculum. On the other hand, the principal objective behind the creation of this course in the context of this study is to determine whether students who undertake this supplementary integrated course retain greater

macroscopic anatomical knowledge and demonstrate enhanced performance in related assessments.

The following paragraphs will delve into the course conceptualization utilizing the backwards design method. Here, the course's conceptualization will remain focused on the course itself, without considering the overarching intent of the study mentioned earlier to influence the contents and desired objectives of the course design. This distinction is particularly important, considering that the research question of this study solely revolves around the integration of radiology into the preclinical curriculum, rather than the development of a supplementary course aimed at enhancing anatomy assessment outcomes.

2.2.2 Analysing learners and context

Prior to delving into the development of the course, it is essential to describe how the incorporation of this course fits into the standard curriculum of the third preclinical semester in the dentistry degree programme at Charité – University Medicine Berlin. This course can be distinguished from conventional university courses. This conceptualised course is unique, in that it operates within the framework of another class, rather than being conducted independently.

To establish initial context, the dissection class into which the course is integrated will be summarized, along with the participating students and their existing level of knowledge. The following information was retrieved according to the regulations regarding studies and examinations for the dentistry course at the Charité – University Medicine Berlin. (Berlin, 2021)

In the third preclinical semester of the dentistry degree programme at Charité, students are instructed in macroscopic and microscopic anatomy. The overarching theme in the subject of anatomy in this semester is the head and neck region; a detailed view of the topics covered is seen in Table 2. Students attend a lecture series on macroscopic and microscopic anatomy and take part in a dissection course.

Table 2 Anatomy lecture series in the 3rd preclinical semester

Semester	Macroscopic anatomy lectures: topics covered

3	• Skull
	  ○ Internal/external skull base
	  ○ Mandible, maxilla, palate
	  ○ Cranial fossa
	  ○ Pterygopalatine fossa
	• Nasal cavity
	  ○ Paranasal sinuses
	• Orbit
	• Neck
	  ○ Regions, fasciae, lodges, structures, muscles
	  ○ Mimic musculature
	• Pharynx
	  ○ Peripharyngeal spaces with contents
	  ○ Act of swallowing
	  ○ Pharyngeal arches, pharyngeal pouches
	• Larynx
	  ○ Voice production
	• Oral cavity
	  ○ Tongue
	  ○ Teeth, innervation and anaesthesia of the teeth, periodontium, dental pulp, tooth development
	  ○ Temporomandibular joint
	  ○ Masticatory muscles, masticatory muscle reflexes
	• Salivary glands
	• Arteries / veins of the head (including vascular anastomoses), lymphatic drainage
	• Facial development
	• Overview of the nervous system, cranial nerves, cervical plexus, cervical cord

Furthermore, students undergo a performance assessment that consists of two partial oral examinations on cadavers. Early in the semester, students take an examination assessing their knowledge of superficial head and neck structures, followed by a second assessment at the semester's end, which tests their comprehension of deeper anatomical regions within the head.

For the dissection course students are divided into 3 to 4 groups each assigned to a different tutor. In the interest of allowing a comparison of performance, the course "Clinical Anatomical Imaging of the Head for Dental Students" was only offered to one of these groups per round, making this the intervention group. The remaining students represent the control group, which follows the regular, unaltered curriculum.

The dissection course is held in parallel to the regular macroscopic anatomy lecture but has an initial delay. Thus, it can be assumed that students already know the anatomical regions discussed in each unit of the course from the previous lectures and they can practise and apply the previously acquired knowledge.

The anatomical topics already taught in the first and second preclinical semesters represent the students' prior knowledge. These being, in the first semester, a preclinical course where general anatomy as well as skull bones were discussed, and in the second semester the systematic and functional anatomy of the thorax, abdomen, and retroperitoneal space.

Students already have had a dissection course in the 2nd preclinical semester, so that the basic features of dissection are already familiar to them.

They will however have a knowledge gap in radiology, which is only dealt with as a subject in the first clinical semester of the dental medicine degree programme. So, it is to be assumed that their knowledge of radiology is lacking.

When students must deal with pathologies in imaging it is worth noting that they will be unfamiliar to them. The necessary clinical context will and must be explained within the course.

2.2.3 Step 1: identify desired results

When examining the intended learning outcomes (ILO) of the course, these can be divided into three sections, each indicating various levels of priority (Wiggins and McTighe, 2005).

Worth being familiar with:

- Understanding the basic mechanisms of x-ray, CT, MRI and cone beam computed tomography (CBCT) imaging techniques.
- Knowing about different diseases that affect the head and neck area.
- Detecting abnormalities within radiological images of the head and neck region.

Important to know and do:

- Orientating themselves within an CT/CBCT/MRI/conventional x-ray image of the head and neck region.
- Differentiating between various methods in medical imaging.
- Describing CT/CBCT/MRI/conventional x-ray images of the head and neck region.
- Understanding how challenging anatomical structures relate to one another within the head and neck using three-dimensional imaging.

Enduring understanding:

- Understanding the different indications for each discussed imaging technique.
- Interpreting CT/CBCT/MRI/conventional x-ray images of the head and neck region.
- Enhancing their understanding of topographical and spatial relationships within the anatomical structures of head and neck region.

Other intended goals:

- Gaining enthusiasm for the field of anatomy by understanding its clinical relevance.

After establishing the main instructional goals (equating to the enduring understanding), the framework outlined in Table 3 was used to further address the essential questions, knowledge and skill objectives, transfer goals and real-world relevance:

Table 3 UbD stage 1 – Desired results. Adapted from (McTighe, 2023)

<table>
<tr><th colspan="3">Stage 1 – Desired results</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS

• Understand the different indications for each discussed imaging technique
• Interpret CT/CBCT/MRI /conventional x-ray images of the head and neck region
• Enhance their knowledge of topographical relationships within the anatomical structures of head and neck region</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to independently use their learning for…
• Patient diagnosis and treatment planning
• Patient education
• Interdisciplinary collaboration and continuation of their education</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDING
Students will understand that…

the irregularity in tissue appearance is a result of the imaging technique that was employed. They will understand the correlation between their requirements for imaging and specific techniques, as well as acquire the ability to identify anatomical structures within these images.</td><td>ESSENTIAL QUESTIONS

• How do the different imaging modalities differ in their applications and usefulness in diagnosing head and neck conditions, and when is each modality most appropriate?
• How can one utilise the knowledge of normal radiographic findings to differentiate between healthy and pathological conditions?
• What are common diseases and conditions of the head and neck region that can be identified through imaging and what are the typical imaging characteristics of these conditions?</td></tr>
</table>

	Acquisition	
	Students will know…	*Students will be skilled at…*
	• the anatomical structures in the head and neck region that are relevant to dental practice and their radiographic analysis • how to discriminate between various imaging modalities and understand their applications • what the physiological radiographic appearance of head and neck anatomy across different imaging modalities looks like • key-points about the common conditions and diseases that affect the head and neck region and can be identified through radiographic analysis	• making sense of what imaging technique (MRI, CT, X-ray) was employed from observing an image, as well as describing what they see • interpreting images with reference to discussed anatomical structures and being able to identify anatomical structures, as well as recognizing obvious abnormalities

2.2.4 Step 2: determine acceptable evidence

To evaluate student learning, various strategies are carried out, as summarized in Table 4. In each teaching unit, a tutor-led group discussion is carried out to review anatomical background knowledge. At this point, informal oral questions are utilized to ensure consistent foundational anatomical knowledge among all students before attempting to find the same structures in imaging. Students then work in groups to label normal radiographic findings and then to assess clinical case studies. At the end of the TU, the tutor gives feedback and confirms answers presented by students within a group discussion of results.

Table 4 UbD stage 2 – Evidence and assessment. Adapted from (McTighe, 2023)

Stage 2 – Evidence and assessment	
Evaluative Criteria	**Assessment Evidence**
• Anatomical Knowledge • Accuracy of Radiographic Interpretation • Differentiation of Imaging Modalities	PERFORMANCE TASK(S): • Formative assessments during tutor-led revision (class participation) • Group work on normal radiographic findings + on clinical case studies (report, case analysis, class participation)
	OTHER EVIDENCE: Observation through questioning in class

2.2.5 Step 3: plan learning experiences and instruction

While students possess familiarity with the anatomical structures of the presented subjects, they lack prior exposure to radiology. Therefore, when designing learning experiences, it is necessary to consider the following: firstly, students must acquire the skills to apply their anatomical knowledge in a radiological context. Only thus can they proceed to identifying anatomical structures through various imaging techniques and navigate these techniques effectively.

To this end, students must receive an introduction to various imaging techniques at the very beginning of the course. However, not all methods of imaging are covered in this course, as instruction is limited to MRI/CT/CBCT and classical radiography. Ultrasound and nuclear medicine are excluded from the course, given that these methods of imaging are not significantly used in dentistry, and there is evidence which shows that students do not see value in these methods for the integrated teaching of anatomy and radiology (Heptonstall et al., 2016).

To facilitate students' awareness of the anatomy that is under discussion via imaging, it is crucial to initially present the discussed anatomical region through physiological examples across diverse imaging modalities. After which, to enhance their ability to

distinguish between physiological and pathological structures, clinical cases related to the topic under consideration are provided.

Thematically, the course revolves around imaging within the head and neck region. However, it is important to note that the comprehensive anatomy of the entire head and neck is not covered or analysed in the imaging context of this course. The content of the teaching units will be limited to topics that have a direct connection to dentistry or present a higher relevance in the dental context. Also, the presented pathologies must be easily imaged and viewed as an introduction to radiology.

The main topics of the course are outlined in Table 5 and are as follows:

- Introduction to imaging
- Skull bones
- Oral cavity
- Infratemporal fossa, masticatory muscles
- Salivary glands
- Teeth
- Temporomandibular joint
- Nose
- Paranasal sinuses
- Orbit
- Larynx
- Pharynx
- Vessels in the head and neck region

The course is designed to span 7 weeks, with the final week dedicated solely to data collection, thus providing 6 weeks for instructional activities. Following an evaluation of the anatomical regions for discussion and the corresponding imaging techniques that students should grasp, a curriculum plan was formulated. This plan clusters related topics and anatomical regions together in a teaching unit, while establishing connections between each main theme and pertinent clinical cases.

Table 5 Outline of the course "Clinical Anatomical Imaging of the Head for Dental Students"

Week	Topic	Clinical cases
Week 1	• Introduction to imaging (*with a focus on diagnostic imaging in dentistry)*. Discussed methods: X-Ray, CT, CBCT, MRI. • Skull Bones	• Skull Bone Fractures • Le-Fort I-III
Week 2	• Oral cavity • Masticatory muscles • Salivary glands	• Salivary Stones • Cleft lip and cleft palate • Tongue carcinoma
Week 3	• Teeth • Temporomandibular joint	• Caries diagnosis • Evaluation of prosthetic and restorative dental work • TMJ disc displacement
Week 4	• Nose • Paranasal sinuses • Orbit	• Odontogenic sinusitis • Blow-out fracture
Week 5	• Pharynx • (Larynx)	• Tonsillitis • Zenker's diverticulum
Week 6	• Larynx	• Phonation on a CT
Week 7	• Performance Assessment • Feedback Forms	-

The fundamental framework of the TU's can be summarized in Table 6 and consists of the following steps:

1. Revision of macroscopic anatomy of the unit's topic

Learning Experience:

- A quick revision of the macroscopic anatomy of each region is orally conducted by the tutor. Students are involved in the revision and informally quizzed on their knowledge.

2. Introduction to anatomical structures in imaging and transition to radiology

Each anatomical region is presented in imaging techniques using physiological examples. This introduction helps students to become familiar with how the structures appear in various imaging modalities and assists students in reorienting themselves within the overarching theme of the course. The tutor explains how anatomical knowledge translates into identifying structures in imaging. Students can at this point bridge the gap between their existing anatomical understanding and radiology.

Learning Objectives:

- Understanding of how anatomical structures appear in different imaging techniques.
- Application of anatomical knowledge to identify structures in imaging.

Learning Experience:

- One or two physiological examples of the discussed region in different imaging modalities is presented. Understanding of how to apply anatomical knowledge into radiology.

Activity:

- X-rays, CTs, CBCTs or MRIs are used to illustrate how structures look in different imaging methods.
- Students are asked to label structures on print outs of x-rays, CTs, CBCTs or MRIs.

Discussion:

- Facilitate a class discussion on the differences and similarities in appearances across imaging techniques. Discuss the connection between anatomy and radiology, allowing students to share their insights.

3. Clinical Case Studies:

Introduce clinical cases that pertain to the specific anatomical region under discussion. These cases will help students understand the real-world application of their knowledge and how imaging is used in diagnosing and treating patients.

Include examples of both physiological and pathological structures in the clinical cases. This will enable students to distinguish between normal and abnormal findings in imaging, a crucial skill for radiology.

Learning Objectives:

- Understand the clinical relevance of anatomical structures in imaging.
- Apply knowledge to clinical “real-world” situations.

Learning Experiences:

- Introduce clinical cases related to the discussed anatomical region.
- Engage in interactive exercises and discussions. Encourage students to review each other's interpretations and provide constructive feedback.

Activity:

- Analyse the cases, identify structures in the images, and discuss the clinical implications.

Group Work:

- Divide students into groups to analyse cases, encouraging different perspectives.
- Interpret imaging findings and discuss the clinical significance in a group setting.

In terms of class materials, the sourcing primarily involved normal imaging cases and the corresponding clinical cases, predominantly obtained from Radiopaedia.org. This online platform specializes in radiology resources, offering an extensive collection of radiology cases, images, and educational content. While the majority of course cases were drawn from this source, it is important to note that not all cases originated there. Nevertheless, all cases were meticulously referenced in the course handouts. The presented imaging and cases were the creative work of collaborators. Subsequently, prompts were integrated into the case presentations during the course conceptualization to facilitate student learning.

Materials, including imaging and cases, were provided to students in hard copy format, accompanied by video files when an in-depth review of three-dimensional scans was required. Students were encouraged to bring their laptops or tablets for this purpose.

Throughout the entirety of the course, students had access to materials in the dissection room, including cadavers, models, and atlases, to complement their learning experience.

Table 6 UbD stage 3 – Learning plan. Adapted from (McTighe, 2023)

Stage 3 – learning Plan
Summary of Key Learning Events and Instruction
1. Tutor-led revision of anatomical background knowledge
2. Group work on normal radiographic findings
3. Group work studying clinical cases
4. Tutor feedback and confirmation

2.3 Assessment of student performance

2.3.1 Introduction to the student assessment form

The student assessment form was developed as a tool to evaluate the effects of the conceptualized course "Clinical Anatomical Imaging of the Head for Dental Students". The aim is to assess whether the integration of radiology in preclinical anatomy classes had any effects on student performance in anatomical tests. To test this possibility, both the intervention and the control group undertook this evaluation to enable a direct comparison of both groups. Participation was, however, voluntary.

2.3.2 Development of the student assessment form

The development of this assessment form drew upon the content covered in both the dissection course and the macroscopic anatomy lecture. Three different categories of questions were developed to evaluate various aspects of student learning. The primary focus was placed on the labelling of anatomical structures on cadaver images, as this represents the primary skillset acquired and trained during the dissection course. In the second set of questions, anatomical connections were tested in a table completion format, assessing whether students could apply their knowledge of topographical relationships beyond simple identification on the cadaver. The third block of multiple-choice questions (MCQ) received a lower point allocation. They aimed to test students' broader comprehension of anatomical structures and their functions.

This assessment falls under the category of summative, objective, formal and criterion-based assessment.

2.3.3 Structure and content of the student assessment form

The assessment form consists of three blocks of questions:

a) Labelling of anatomical structures on a cadaver image, question 1

Students were provided with an image of a cadaver where the suprahyoid and infrahyoid muscles along with its neighbouring structures were depicted. In the question, students had to correctly identify the anatomical structures marked with numbers.

b) Completion of tables that outline the connection between anatomical structures, questions 2 and 3

Here students were firstly asked to indicate the communications of the pterygopalatine fossa with its surrounding structures. Presented within a table correlating "connection provided by" with "content," students had to fill out the missing information.

Secondly, there was a three-row table that dealt with the three main branches of the trigeminal nerve. Students were asked to label these branches and specify their respective points of exit from the cranial base, as well as indicate the structures which they traverse.

c) MCQ, questions 4-6

The three MCQ presented to students assessed their understanding and knowledge of various anatomical structures and functions. Questions covered various aspects of anatomy, including the muscles of mastication, details of the facial nerve (nervus facialis), different structures within the oral cavity, and even embryology. Students were required to select the correct statement from multiple options provided for each question.

2.3.4 Point allocation and grading rubric

Table 7 Point allocation on the assessment of student performance form

Question	**1**	**2**	**3**	**4**	**5**	**6**
Maximum achievable points	22	6	9	1	1	1

The form was only designed with the intention of collecting data and so did not hold any significance for the participating students themselves or their academic performance. The questions were designed to yield a dichotomous response, being either correct or incorrect, so that a uniform point allocation was employed. Each correctly answered question was assigned a value of 1 point, while incorrect responses received 0 points.

Thus, the grading of this form was only assessed in terms of the accumulated point number and the corresponding percentage. A "pass or fail" system was not relevant to the objectives of data collection. The assignment of points was not reflective upon the level of question complexity, with utilizing Bloom's taxonomy model utilized here to classify questions (Bloom, 1969). This is seen when comparing Table 7 and Table 8. The goal of this form was not to administer fair grading to the students. Instead, the primary objective was to gain an effective way to compare data between the two groups, enabling an analysis of the different outcomes in performance.

Table 8 Bloom's taxonomy level associated with the questions on the student performance assessment form

Question	Bloom's taxonomy level	Explanation
1 Labelling of anatomical structures on human cadaver images	Knowledge	Students are asked to recall and identify anatomical structures based on visual markers, which primarily falls within the "remembering" aspect of Bloom's taxonomy
2, 3 Filling out tables about the connection between anatomical structures	Comprehension	This task requires comprehension and organization of information, aligning with the "understanding" level of Bloom's taxonomy
4, 5 and 6 MCQ	Application	Analysing the provided options and selecting the correct answer involves applying knowledge to specific situations, fitting within the "application" level of Bloom's taxonomy.

A grading rubric was created designating the correct answer and acceptable answer variations for each question. Common and foreseeable incorrect answers were also listed. The grading rubric was reviewed and approved by a senior member in our research group.

2.4 Student feedback survey

2.4.1 Development of the student feedback survey

Students of the intervention group took the feedback survey after completion of all teaching units, while the control group was excluded due to their non-participation in the course.

The objectives of the feedback survey were the following:

- Retrieval of basic demographic data of the intervention group.
- Evaluation of students' attitude towards the integration of radiology in their anatomical and preclinical education.
- Allowing for student self-assessment on their gained knowledge after having attended the integrated course.
- Obtaining general feedback on course content, teaching methods, course organisation and overall learning experience.

Strategies when composing the feedback form included the following:

- Usage of neutral language.
- Employment of a combination of different question types for a comprehensive evaluation: A mixture of closed-ended questions (dichotomous yes/ no questions, MCQ), one open-ended question, one nominal scale, and even scaled 10-point Likert scales were employed. Preston and Colman (Preston and Colman, 2000) found that 10-point Likert scales are perceived by participants as the easiest to navigate and facilitate a greater expression of opinions. An even scale also forgoes the central neutral answer and with that, the social desirability bias (Garland, 1991).
- Formulation of clear and concise questions while avoiding leading questions.
- Organisation of the form into categories as to facilitate navigation.
- Enforcing anonymity to ensure honest feedback.

The feedback survey was broken down into four sections and totalled up to 25 questions.

2.4.2 Structure and content of the student feedback survey

Section one – Demographic Data, questions 1.1 – 1.3

Here, students were asked to indicate their gender, age and whether they had any previous experience with human or dental medicine subjects before enrolling in the dentistry course at Charité (MCQ). This last question was posed to assess whether the intervention group potentially had significantly greater knowledge in the medical field. For example, a student who has previously completed training in dental hygiene would have had contact with imaging beforehand.

Section two – Integrated teaching of anatomy and radiology, questions 2.1 – 2.7

Two ten-point Likert scales were employed to have students access the importance of integrating radiology with anatomy, as well as the pertinence of incorporating radiology classes into the preclinical semesters. This was followed by a series of closed-ended inquiries encompassing dichotomous (yes/no) and multiple-choice formats. These questions aimed to understand students' preferences concerning the modality of integration. Specifically, considerations encompassed the voluntary or mandatory nature of participation, potential integration within anatomy classes (with options including lectures or dissection sessions), or a distinct arrangement. Furthermore, the survey sought input on the envisioned frequency of such integration, expressed in terms of hours per semester.

Section three – Student self-assessment of gained skills and knowledge, question 3

Nine desired learning objectives from the course conception were listed for students to self-evaluate their individual learning outcomes. The question begins with the prompt “After attending the integrated course I have learned…” followed by the learning objectives. These must be individually evaluated by students on 10-point Likert Scales.

Section four – Evaluation of the course, questions 4.1 – 4.6

An amalgamation of closed questions: multiple-choice, yes/no questions, and 10-point rating scales were employed to gain students perspectives regarding the integrated course. Students were queried on aspects such as content, scope, and overall perception concerning its relevance to their future careers and personal satisfaction.

2.4.3 Participation, anonymity, and form archiving

Participation in the feedback survey was voluntary. The form was distributed in paper format and the answers were archived solely in this format.

Anonymity and data privacy was discussed with participating students. No personally identifiable information, such as names, student IDs, or email addresses were requested in the survey. To further safeguard anonymity, the demographic data was aggregated and only presented in the context of describing the cohort.

2.5 Intervention

2.5.1 General information

The course was integrated in the anatomical dissection course of the third preclinical semester in the dental medicine programme at the Charité. Initially, this course was offered in the winter semester of 2022/2023, that ran from 17th October 2022 to 10th February 2023. It was then repeated in the summer semester of 2023, with the lecture period spanning from 17th April 2023 to 28th July 2023.

The modified curriculum was exclusively followed by the intervention group, comprising 14 students in the first round and 13 students in the second round, totalling 27 students who participated in the course "Clinical Anatomical Imaging of the Head for Dental Students". Students in the control group followed the normal curriculum. The control group consisted of 29 students in the first round, and 23 students in the second round, making a total of 52 participants in the control group.

2.5.2 Integration into the anatomical dissection course of the third preclinical semester of the dentistry degree at Charité

The regular dissection course spans over 8 weeks, with students attending two 90-minute teaching units each week, totalling 180 minutes of weekly instruction. The last week (nr. 8) consisted solely of a dedicated day for the examination.

A TU for the course "Clinical Anatomical Imaging of the Head for Dental Students" was developed to complement each week of the dissection course as outlined in Table 5. However, this conceptualized course ended one week prior to the dissection course.

As mentioned before, each weekly teaching unit required approximately 30 minutes to complete, and the instructor of the course was at liberty to integrate the content in a manner and time limit of their choosing during the respective week. The instructor in both

rounds of this study was an anatomy lecturer and dentist, assisted by tutors, who were mainly dental students of higher semesters.

2.5.3 Teaching unit “Pharynx/ (larynx)”: in-depth description and conceptual illustration

To illustrate the concept of the conceptualised clinical-anatomical course "Clinical Anatomical Imaging of the Head for Dental Students", the TU on “Pharynx/ (larynx)” will be used as an example and described in detail:

A quick oral revision of the macroscopic anatomy of the pharynx and larynx is conducted by the tutor.

Students are then firstly presented with CT slices that depict normal findings of the larynx and pharynx where they must orientate themselves within the individual CT slices and identify the indicated structures. Both individual and group work are encouraged to complete the exercises. When finished, students obtain the correct answers from the tutor.

Subsequently, two distinct clinical cases were presented. All cases in the course were carefully chosen to encourage students to apply their anatomical knowledge in solving the depicted problems. While the focus remains on anatomical aspects, any relevant clinical issues are explained when needed. CT scans and the swallow test were distributed to students in the form of video files for their analysis and study.

In the first case, this clarification was provided after students analysed the CT scans. However, in the second case, the clinical context was introduced before imaging. The rationale behind this distinction is that in the first case, students were able to deduce altered structures and their implications for the patient's symptoms without prior knowledge of Zenker's diverticulum. In the second case, students lack clinical familiarity, and even by being given the classic symptoms of tonsillitis in their question prompt, they would be highly likely to end up exploring the entire pharynx and larynx through the CT scan looking for a cause. This would consume a considerable amount of time. Therefore, by providing the clinical context beforehand, students can concentrate on more specific questions related to the case, such as bilateral involvement or the presence of an abscess. This is how the clinical context was implemented into teaching throughout the entire project.

The cases presented within this teaching unit were sourced from Radiopaedia.org. The initial case of this TU was contributed by Andrew Dixon, while the subsequent one by RMH Core Conditions (a joint project between The Royal Melbourne Hospital and Radiopaedia.org). Accompanying images are products of their own creation. Prompts were incorporated into the case presentations to guide student learning.

The presented cases were the following:

Case 1) Pharyngeal pouch (Zenker's diverticulum) (Dixon, 2010) "*An 80-year-old patient suffers from chronic dysphagia. In addition, she complains of intense halitosis and frequent vomiting. A chest X-ray is ordered (Figure 3). What do you notice?"*

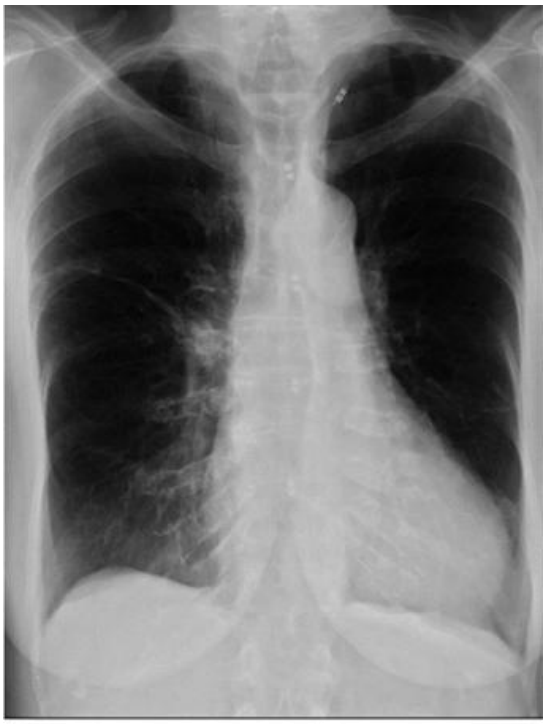

Figure 3 Pharyngeal pouch showing an air-fluid level is projected at the superior mediastinum. X-Ray. (Dixon, 2010)

"A fluoroscopy is then performed (Figure 4) to be able to visualize the motion of swallowing. For this, the patients swallow barium-coated food or liquid. This exam consists of a continuous X-ray technique that allows the path of the food/liquid to be closely observed."

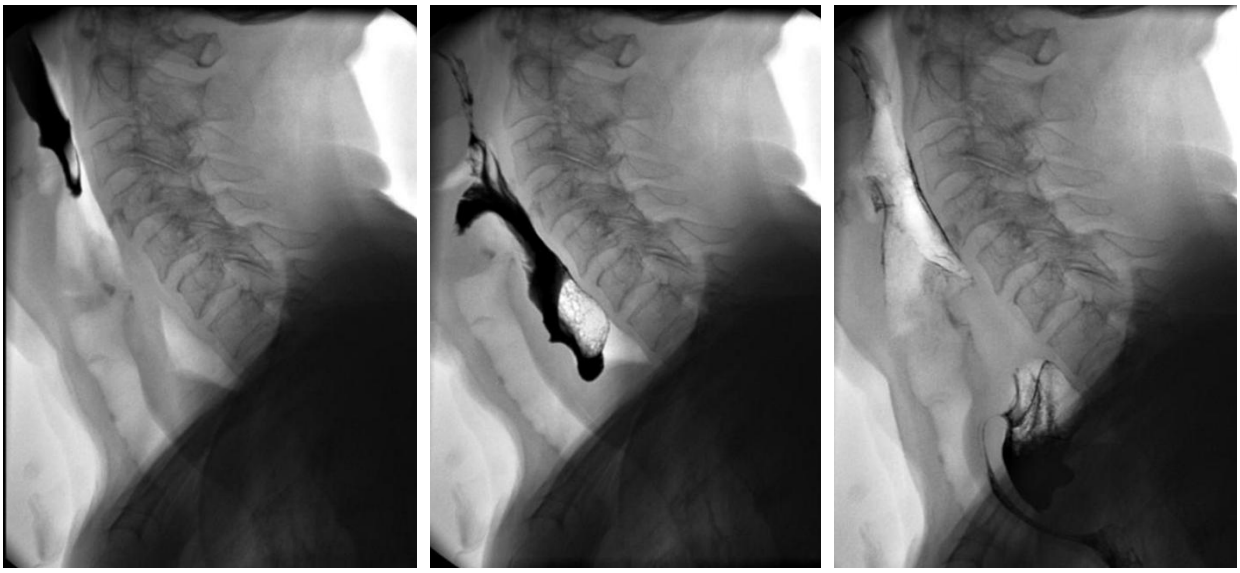

Figure 4 Pharyngeal pouch containing contrast. Barium swallow test. X-Ray. (Dixon, 2010)

“Lastly, a CT is also ordered (Figure 5). Do you recognize any changed structures that would have causes the patient's symptoms?”

Figure 5 Pharyngeal pouch arising from the midline of the posterior wall of the distal pharynx near the pharyngoesophageal junction and showing an air-fluid level. CT with contrast. (Dixon, 2010)

Following the case presentation, students are encouraged to engage in peer discussions and access the case imaging. The tutor subsequently highlights to the entire group the specific pathological structures and elucidates how these findings correspond to the patient's symptoms. The tutor identifies the condition as Zenker's diverticulum and introduces the pathology of this disease to students.

Case 2) Tonsillitis (Conditions, 2010)

Students are given a brief introduction to the topic of tonsillitis. They then receive the prompt:

"A patient visits his general practitioner. He has been experiencing a severe sore throat for the past 5 days. Despite conventional medication, the pain has worsened. Overnight, he has developed reduced neck mobility accompanied by pain. A CT scan is performed (video file). Does the patient have tonsillitis? If so, identify this on the CT scan. Are both sides affected? And examine carefully: is an abscess present?".

After access is given to the CT scan for approximately 5-minutes (Figure 6), the tutor intervenes and identifies the areas on the scan showing bilateral involvement, as well as in this case, the absence of an abscess. The tutor discusses the clinical significance of an infiltration of the abscess into the parapharyngeal space and its subsequent descent into the mediastinum, which could lead to mediastinitis.

Figure 6 The palatine tonsils are enlarged and hyperemic bilaterally. CT. (Conditions, 2010)

2.6 Data collection

Data collection encompassed the two distinct forms: the student feedback survey (solely applicable to the intervention group) and the assessment of student performance form (filled out by both the intervention and control group).

Collection of both forms took place on the penultimate day of the dissection course. This also marked the final course day before all the students took the macroscopic anatomy final exam. This timing was intentional, as it was assumed that students' knowledge would be at its peak, geared towards preparing for the upcoming exam. On the final week of the dissection course, students of the intervention group had already completed all teaching units of the clinical-anatomical course "Clinical Anatomical Imaging of the Head for Dental Students".

The student feedback survey was distributed to the intervention group at the beginning of the dissection course teaching unit. Students were given time until the end of class to complete the forms and return them to the tutor.

Then, both the intervention and control group could fill out the student assessment form. To ensure sufficient time for this task, the dissection course ended 10 minutes early, granting a total of 30 minutes for completion of the forms. The remaining 20 minutes were taken from allocated break time.

Participation in the student assessment form was voluntary for both the intervention and control group. However, students were encouraged to participate, as they were informed that the form aimed to address potential exam questions and could serve as a "mock exam" for self-evaluation, exposing any knowledge gaps for their upcoming standard macroscopic anatomy exam.

The forms were collected after the 30-minute interval, during which students were under exam conditions. Access to external resources such as books, atlases, notes, or electronic devices (e.g., mobile phones or computers) were not allowed. Interactions or discussions with peers during the form completion were prohibited. These conditions were always supervised and controlled for.

During the first round of intervention, the data collection occurred on the 4th of January 2023, and during the second round it was on the 15th of June 2023.

2.7 Statistical analysis

Overall, two separate questionnaires were analysed: the student assessment form and the student survey. Consequently, data analysis was approached using different respective methods (see subsections 2.7.1 and 2.7.2).

Data preparation, as well as the construction of tables as graphs was conducted using Microsoft Excel for Office 365 (version 2406, Microsoft Corporation, Redmond, WA, USA) and Microsoft Word for Office 365 (version 2406, Microsoft Corporation, Redmond, WA, USA). Statistical analysis was performed with IBM SPSS Statistics (version 29.0, SPSS, Chicago, IL, USA).

2.7.1 Data analysis – student assessment form

Student assessment forms were marked with an anonymous identification number (ID) and aggregated into two groups: the control group and the intervention group. Students indicated if they had been taught by the tutor with the altered curriculum by checking a box at the beginning of the assessment form. Those students represent the intervention group, while the ones that did not check the box constitute the control group.

Each assessment form was graded using the grading rubric and points for each question were imported into Microsoft Excel. For each correctly answered term in questions 1a, 1b, 2 and 3, one point (value=1) was attributed, and points were summed up to a total score. Each correctly answered MCQ was also attributed one point (value=1). Missing and invalid/incorrect answers were all assigned zero points. For each participant, the total of obtained points was calculated and converted into the corresponding percentage for the assessment.

These metric values were entered directly into SPSS. For an initial overview of data, key descriptive statistics were applied. Hypothesis testing followed with an independent samples two paired t-test. The tested hypotheses were: “H0: The integrated course does not lead to better exam results than the normal curriculum” and “Ha: The integrated course leads to better exam results than the normal curriculum”. The significance level was set at 0.05.

2.7.2 Data analysis – student feedback survey

All student feedback surveys were marked with an anonymous ID number and results were manually imported into MS Excel. The retrieved data was then appropriately coded for further statistical analysis with SPSS. Likert scale results were directly adopted (numerical values 1-10), while MCQ were assigned nominal values for each possible answer as follows: option a=1, option c=2, option c=3, option d=4. Dichotomous variables, such as yes/no questions, were binary coded (no=0, yes=1). Age (value in years) was set

as a metric scaled value and directly imported as the indicated numeric values and gender was also assigned numeric values: male=1, female=2.

The survey had one free answer question (Question 2.4.1) "*If yes, how many hours?"* where valid answers had to be a real positive number, which if applicable was then transferred directly in its metric value.

Missing and invalid responses were coded using a period ".". All further analyses were conducted using available case analysis (pairwise deletion), where both missing and invalid responses were excluded, while always appropriately adjusting the sample size.

Data was then entered into SPSS whereby each survey question was represented as a variable and data was analysed using descriptive statistics.

Frequency distribution of Likert scales was displayed on histograms and a box plot was created for the visualization of the distribution of responses. For MCQ and yes/no questions, the frequency of responses was counted, and corresponding percentages were represented on pie charts. Values were reported using the median with its interquartile range (25th percentile - 75th percentile). Correlations between Likert scale results were analysed using Pearson's correlation analysis with the respective correlation coefficient (r) and its 95% confidence interval (95%CI).

The mean score of all 10-point Likert scales of question 3, which can be considered as the mean score of students' self-perceived gained knowledge and skills, was calculated and labelled as a new variable "mean knowledge".

Any mention of mean scores throughout the discussion will pertain to 10-point Likert scales. Learning objectives will be considered met above a mean score of 7, which is also the threshold for other statements to be labelled with an "above average" or "considerable" level of agreement by participants. A mean score of 8 is described as a "high level" of agreement.

3 Results

3.1 Student assessment form

3.1.1 Question 1: labelling of anatomical structures on cadaver images

Table 9 displays the results of the control and the intervention group for the first question.

Table 9 Question 1: Results

		N	mean	SD	SEM
Question 1	Intervention group	27	10.78	3.97	0.77
	Control group	52	10.21	3.43	0.48

3.1.2 Questions 2 and 3: completion of tables that outline the connection between anatomical structures, questions 2 and 3

Across this set of questions, the mean score of the intervention group was higher than of the control group, as displayed in Table 10. This difference was not statistically significant, with p(Q2) =0.05 and p(Q3) =0.41, respectively.

Table 10 Questions 2 and 3: Results

		N	mean	SD	SEM
Question 2	Intervention group	27	2.33	2.32	0.45
	Control group	52	1.40	1.73	0.24
Question 3	Intervention group	27	6.48	2.17	0.42
	Control group	52	6.02	2.60	0.36

3.1.3 Questions 4-6: MCQ

The mean scores for questions 4 and 5 were higher in the intervention group than the control group, while question 5 saw a higher mean for the control group by 0.04 points. These results showed no significant differences between groups, with p (Q4) =0.43, p (Q5) =0.75, and p (Q6) =0.21, as shown in Table 11.

Table 11 Questions 4-6: Results

		N	Mean	SD	SEM
Question 4	Intervention group	27	0.54	0.51	0.10
	Control group	52	0.46	0.50	0.07
Question 5	Intervention group	27	0.48	0.51	0.10
	Control group	52	0.52	0.51	0.07
Question 6	Intervention group	27	0.70	0.47	0.09
	Control group	52	0.57	0.50	0.07

3.1.4 Total points

The total scores achieved by students were compared between both groups. The mean achieved score of the intervention group was higher (mean=20.92, SD=6.7, n=26) than the one of the control group (mean=19.42, SD=6.28, n=53). However, there was no statistically significant difference between both groups (p=0.16).

3.2 Student Survey

3.2.1 Demographic Data

A total of 28 students were part of the intervention group and participated in the student survey. Participants had a mean age of 20.67 years, with age ranging from 19 to 25 years. Overall, 71.4% (n=20) of participants identified as female, and 28.6% (n=8) as male. Of the 28 participants, 46.4% (n=13) indicated to not have any previous knowledge in the medical or dental fields prior to starting their dental course at Charité. Of the 15 (53.6%, n=15) that did, 3 participants specified that this previous knowledge was obtained during the completion of a voluntary social year in the medical field, 5 stated that this occurred through the start or completion of an apprenticeship in the medical field, 3 stated to have had professional work experience in a hospital or in a medical practice, 1 had done an internship in a dental office, while two students had both stated to have experience through the start or completion of an apprenticeship in the medical field and through professional work experience in a hospital or in a medical practice, and one participant did not specify further.

3.2.2 Students' perception of the integrated teaching of anatomy and radiology

When asked to evaluate the curricular approach of integrating the teaching of anatomy and radiology on 10-point Likert scales (1= not important,10=very important), students rated the importance of integrated teaching of radiology and anatomy with a mean score of 7.46 (SD=1.86, n=28) (question 2.1), and the teaching of basic radiology in the preclinical phase of their studies with a mean score of 7.54 (SD=1.67, n=28) (question 2.2). Frequencies of responses for both questions are seen in Figures 7 and 8, respectively. The mode for both scales was 8 and only 4 participants rated the scales 4 or lower.

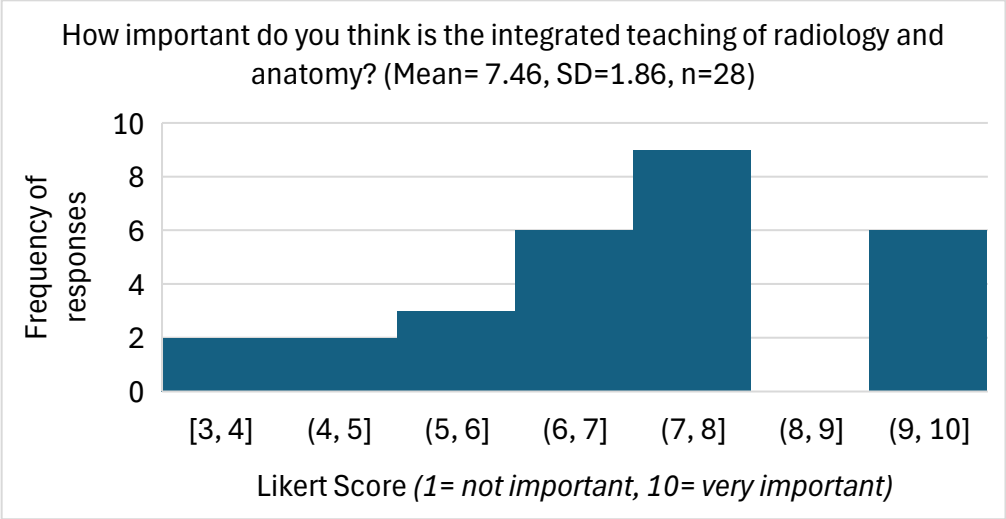

Figure 7 Response Frequency for Question 2.1 of the Student Feedback Survey

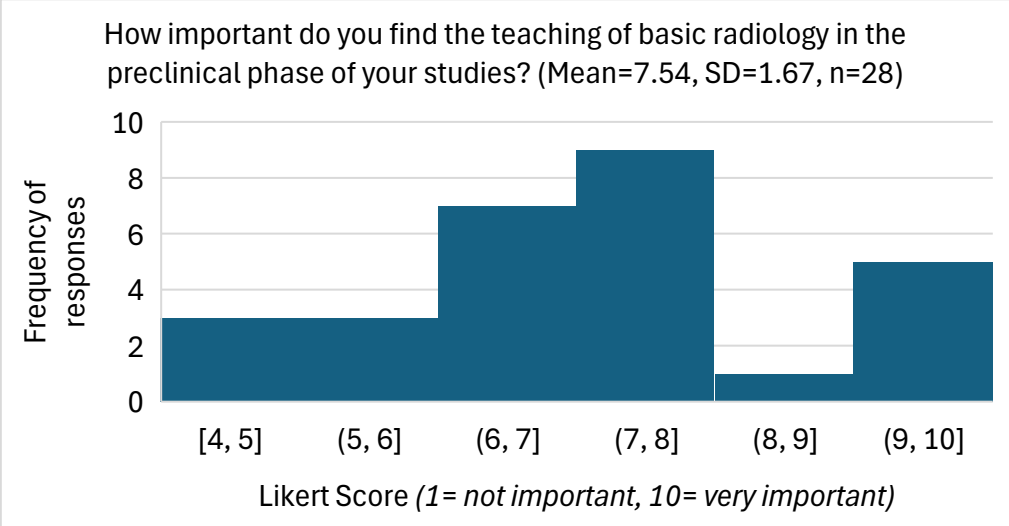

Figure 8 Response Frequency for Question 2.2 of the Student Feedback Survey

A summary of students' perception of the integrated teaching is displayed in Figure 9.

Regarding the method and format of integration, 78.6% (n=22) of participants noted that they would like to have the contents of anatomy lectures discussed in a radiological context every semester, while 21.4% (n=6) would not. However, most students (64.3%, n=18) preferred to not have a specific allocated number of hours in the anatomy lectures solely reserved for this purpose.

The 35.7% (n=10) of students that did want a specific number of hours allocated were further asked to indicate how many hours, and the mean score was 2.29 hours.

The majority would like to have radiology integrated into the pre-clinical teaching of anatomy by having instruction run parallel to or accompanying the dissection course (70.4%, n=19), whereas only 22.2% (n=6) found it to best to be integrated directly into anatomy lectures, always accompanying the covered anatomical topics, and 7.4% (n=2) found it best to be taught separately as stand-alone seminars or lectures.

Students preferred way to be taught radiology in a preclinical setting was in form of group work within the normal anatomy course (70.4%, n=19), followed by lectures (22.2%, n=6) and lastly in the form of self-study in the anatomy course (7.4%, n=2). As for the nature of participation in the preclinical teaching of radiology, 40.0% (n=10) of participants thought that it should be compulsory (integrated as part of the other compulsory courses in anatomy), 12% (n=3) thought that participation should be compulsory (as a stand-alone lecture) and 48.0% (n=12) believed it should be offered as an elective module.

Pearson's correlation analysis demonstrated that the perceived importance of integrated teaching of anatomy and radiology only moderately correlated with the recognized importance of radiological teaching in preclinical years (r=0.4, 95%CI: 0.03-0.67, p=0.01).

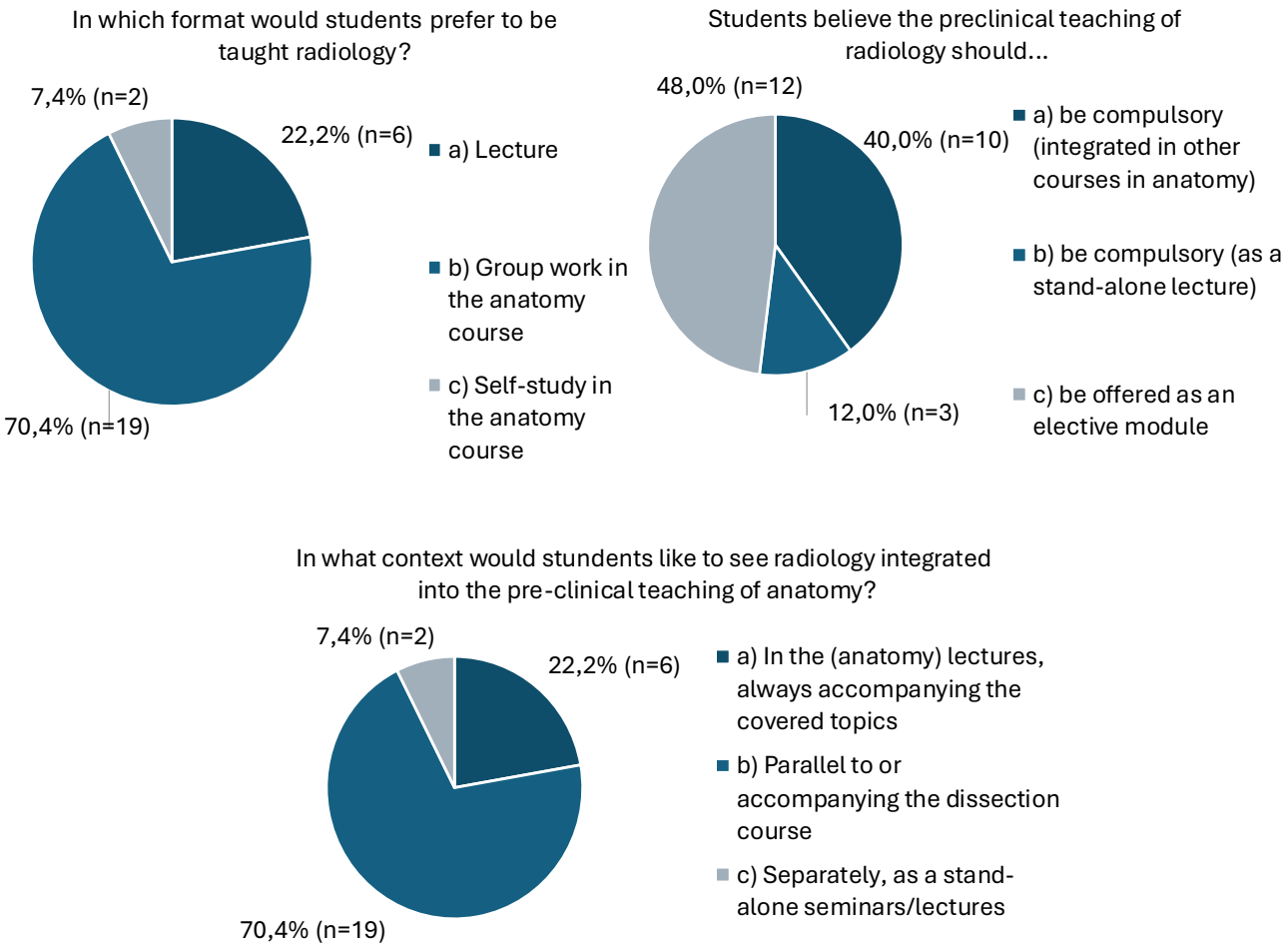

Figure 9 Students' Perception of the Integrated Teaching

3.2.3 Students' self-assessment of gained skills and knowledge

Students self-evaluated their individual learning outcomes regarding desired learning objectives from the course conception (questions 3.1-3.9). The key descriptive statistics for these scales can be found in Table 12. Distribution of responses for these scales are presented in the form of box plots in Figure 10, where one finds the distribution of all 9 scales.

Table 12 Students' self-assessment of gained skills and knowledge on 10-point Likert scales: Key descriptive statistics

	Question 3.1) I can differentiate between different imaging methods.	**Question 3.2)** I understand the basic mechanism of CT/CBCT/MRI/ X-ray. imaging methods.	**Question 3.3)** I can orientate myself within an CT/CBCT/MRI/ X-ray image.	**Question 3.4)** I have improved my knowledge of the topographical relationships of the anatomical structures within the head and neck area.	**Question 3.5)** With the help of three-dimensional imaging, I better understand difficult anatomical structures and their relationship to each other.	**Question 3.6)** My enthusiasm for the subject of anatomy has increased due to the clinical references.	**Question 3.7)** I was able to expand my knowledge of anatomy because I had to apply it in a clinical context.	**Question 3.8)** I can recognize whether radiological images of the head and neck region are physiological or pathological.	**Question 3.9)** I gained an insight into various diseases that affect the head and neck region.
N (valid)	28	28	28	28	28	28	28	28	28
N (missing)	0	0	0	0	0	0	0	0	0
Mean	7.39	6	7.04	7.21	6.46	7.25	7.21	5.43	7.61
Median	8	6	7	8	7	7	8	5	7
Mode	10	5	7, 8	8	7	7	5	5	10
SD	2.47	2.23	1.86	2.13	1.99	1.99	1.87	1.85	2.17
Minimum	1	1	1	1	2	4	4	2	3
Maximum	10	10	10	10	10	10	10	9	10
25^{th} percentile	6.25	5	6	6	5	5.25	5	4	6
75^{th} percentile	9	7.75	8	9	8	9	9	7	10

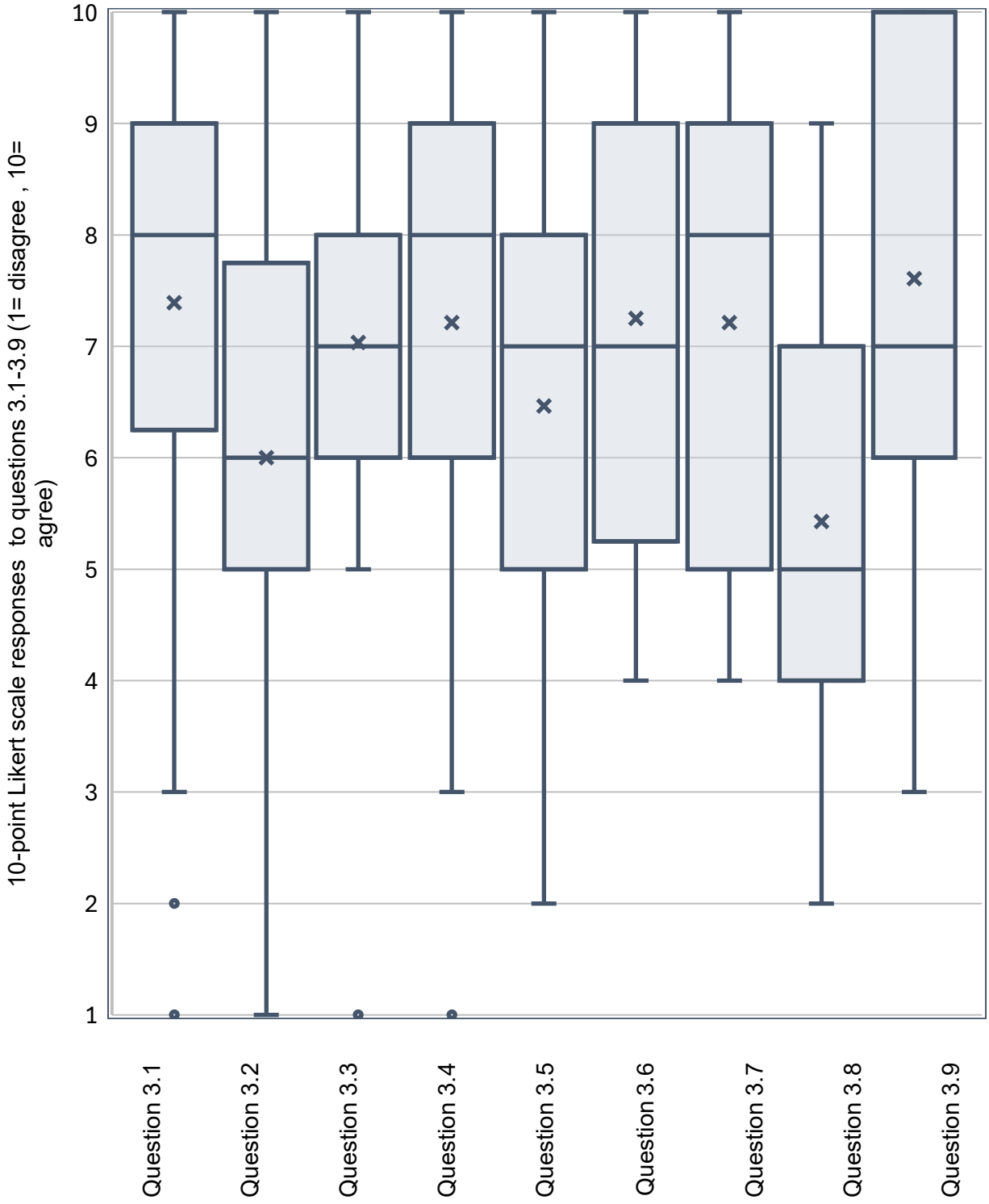

Figure 10 Distribution of Responses for Question 3 (student self-assessment of gained knowledge and skills). The crosses indicate the mean for each question.

The two learning objectives that were regarded as highest achieved by students were “I gained an insight into various diseases that affect the head and neck region.”, with a mean score of 7.61 (SD = 2.17) and “I can differentiate between different imaging

methods.”, with a mean score of 7.39 (SD = 2.47). The mode for both questions was 10, the highest possible score on the Likert scales.

Contrarily, the two with the lowest agreement of participants were “I can recognize whether radiological images of the head and neck region are physiological or pathological.”, where the mean score was 5.43 (SD = 1.85) and “I understand the basic mechanism of CT/CBCT/MRI/ X-ray imaging methods.”, with a mean score of 6 (SD = 2.23). A high standard deviation across all scales is noted.

The median scores highlight generally positive perceptions across all scales, with values always above the midpoint of 5. The highest interquartile ranges (IQR) were observed for “I gained an insight into various diseases that affect the head and neck region.” (IQR: 6-10) and “I was able to expand my knowledge of anatomy because I had to apply it in a clinical context.” (IQR: 5-9), showing a broader range in responses. The lowest IQR was seen for “I can orientate myself within an CT/CBCT/MRI/ X-ray image.” (IQR: 6-8) displaying a higher degree of consensus. Low outliers are present in question 3.1 (at values 1 and 2) and 3.3, and in 3.4 (at value 2), highlighting responses that highly differed from most observations for this category.

3.2.4 Students’ evaluation of the course

Students were asked to assess the amount of case studies that an integrated course should have, evaluating whether the applied quantity in this study (6 case studies) was sufficient, excessive or insufficient. The majority (82.1%, n=23) concluded that the amount of case studies was sufficient. Only 7.1% (n=2) expressed a desire for less and 10.7% (n=3) a desire for more case studies to be incorporated into the integrated course.

A division of opinions was noticeable regarding the allocated time in the course dedicated to solely becoming familiar with normal anatomical findings on CT/MRI/X-ray images. Here 50% (n=14) of participants desired more time reserved for this task, whereas the other half (n=14) found it to be sufficient.

When asked about the possibility of implementing the integrated course into other semesters (here, specifically the second preclinical semester), 78.6%% (n=22) of students were in favour.

Students provided further personal opinions regarding the course on another set of 10-point Likert scales, which's results are summarized in Table 13. Respective response frequencies are depicted in Figure 11.

Table 13 Students evaluation of the course on 10-point Likert scales: Key descriptive statistics

	How important did you find the coverage of clinical/radiological cases in the course?	**How useful did you find the integration of clinical/radiological case studies for your education?**	**How much did you enjoy the integration of the clinical/radiological case studies?**
N (missing)	0	1	1
N (valid)	28	27	27
Mean	6.96	7.56	8.07
Median	7.00	8.00	8.00
Mode	5 and 6	8 and 9	10
SD	1.82	1.72	2.00
Minimum	4	3	2
Maximum	10	10	10

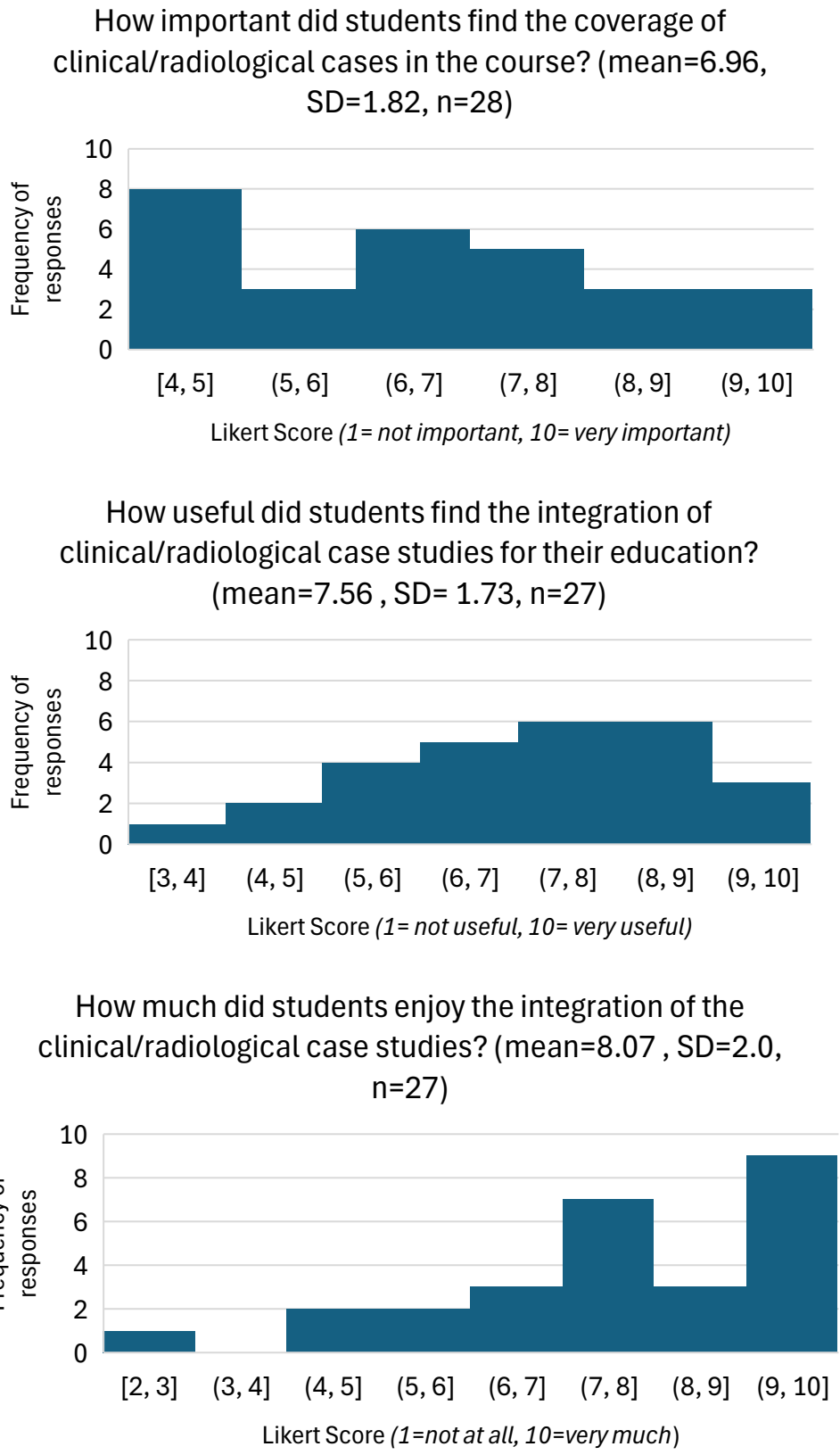

Figure 11 Response Frequency for Questions 4.2, 4.5, 4.6, Student's Evaluation of the course

The highest mean value of the student survey (mean=8.07, SD=2.00, n=27) was attributed towards the regarded enjoyment of the integrated approach to the teaching of students, and it was particularly notable that the most frequently seen answer corresponds to the highest possible value on the Likert scale.

The importance of having clinical/radiological cases covered in class was rated by students with a mean score of 6.96 (SD=1.82, n=28), while the usefulness of the integrated curriculum for student education was rated higher (mean=7.56, SD=1.72, n=27).

A scatter plot is displayed in Figure 12, with the variable “mean knowledge” (n=28) against students’ overall enjoyment of the course (n=27), with a fitted regression line. The Pearson’s correlation analysis revealed a strong positive correlation between students mean self-assessed gained knowledge and skills as well as their enjoyment of the integrated approach, as demonstrated by the positive slope of the regression line (r=0.84, 95%CI: 0.68-0.92). The result is statistically significant with p<0.001.

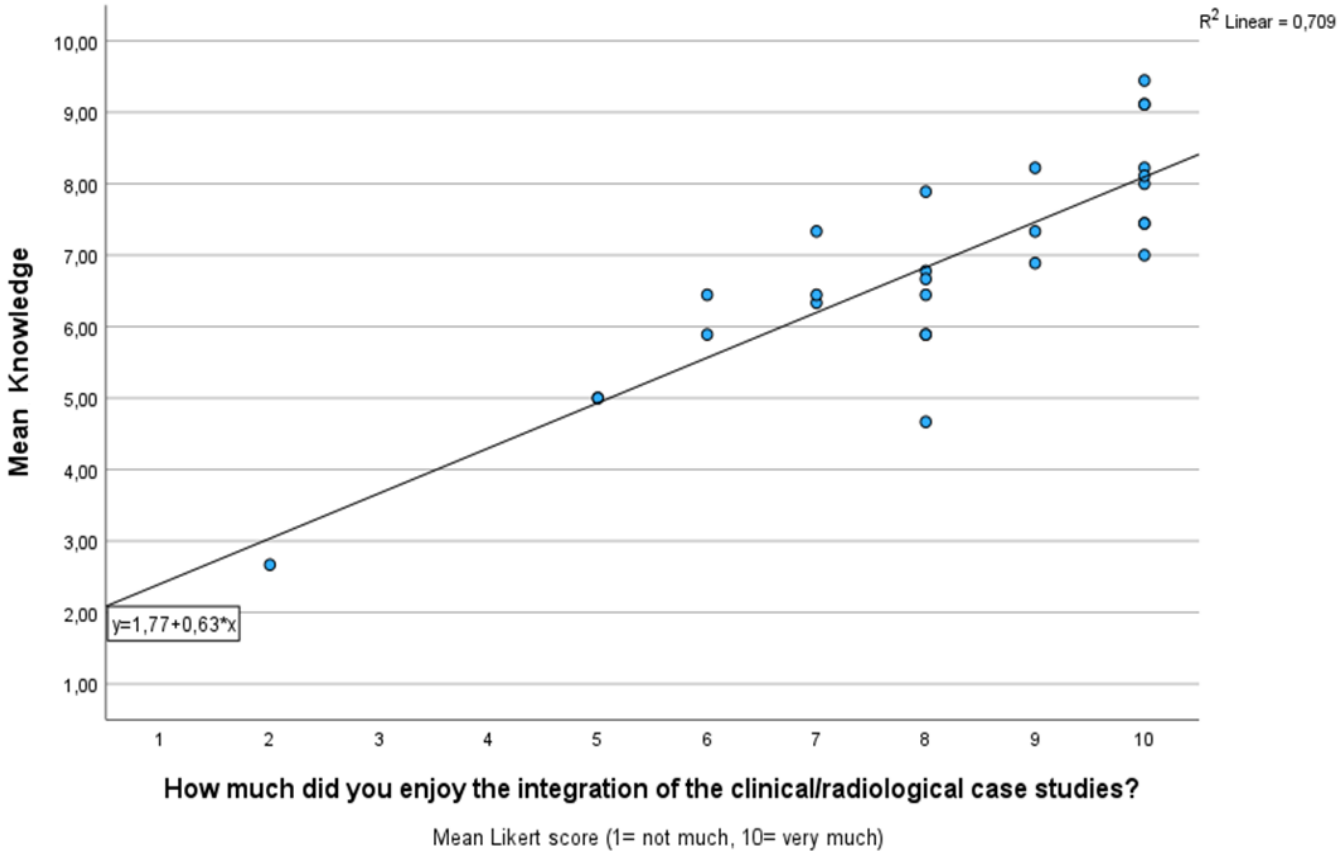

Figure 12 Pearson’s correlation analysis between students’ self-perceived gained knowledge and skills and their enjoyment of the course

A Pearson’s correlation analysis was also conducted between the mean score of self-assessed gained knowledge and skills (n=28) and students’ perspectives on how important the integration of clinical/radiological case studies is for their education (n=27). The correlation analysis revealed a strong positive and statistically significant correlation ($r=0.76$, 95%CI: 0.54-0.88, $p<0.001$).

4 Discussion

4.1 Student performance

4.1.1 Key findings

To assess whether the integrated course had an impact on student performance, both the intervention and control group filled out the student assessment form under exam conditions. The achieved points were summed up and used as a metric to assess their success. Although the mean score of achieved points by the intervention group was, except for one MCQ, consistently higher than the mean score achieved by the control group, these results remained statistically insignificant.

4.1.2 Interpretations and implications

The incorporation of imaging into anatomy education has been seen to have a positive impact on student performance on questions regarding spatial relationships and in general on gross anatomy courses and summative examinations (Lufler et al., 2010, Chew et al., 2020, Paech et al., 2018, Paech et al., 2017, Webb and Choi, 2014). Paech et al. demonstrated, for example, that students exposed to CT imaging during cadaveric dissection achieved 27% higher scores in gross anatomy testing (Paech et al., 2017). Another studied benefit to anatomical student performance is the long term knowledge retention resulting from the integration (Erkonen et al., 1992).

On the student assessment form, there were targeted questions (questions 2 and 3) that assessed students' ability to make connections between anatomical structures. Here, the mean score of the intervention group was higher than that of the control group, falling in line with the research mentioned above. It has been long thought that this is one of the main advantages of incorporating imaging into dissection classes, that helps enhance the understanding of difficult spatial relationships (Pabst et al., 1986, Gunderman and Wilson, 2005, Dettmer et al., 2013, Slon et al., 2014).

The first set of questions on the form had students identifying numerous anatomical structures across the head and neck region. Here, the intervention group also accumulated more points than the control group. This improvement could correlate with the postulated improvement of long-term knowledge retention, as they demonstrated a better ability to label these structures that were studied throughout the 7 weeks.

These two questions represent the first two levels of Bloom's taxonomy, i.e., "knowledge" for question 1 and "comprehension" for question 2 and 3. Here, although without statistically significant results, students of the intervention group outperformed the ones of the control group.

However, in the last question block (questions 4, 5 and 6), the results varied, and the control group even surpassed the intervention group in one question (albeit all still statistically insignificant). Here, students were working in the context of the third level of Bloom's taxonomy: "application". This level demands higher levels of thinking skills and involves using acquired knowledge in new situations, and questions in the MCQ format targeted beyond basic anatomy and visible structures, delving into more theoretical concepts and even embryology.

It could be suggested that for this cohort, the integration of imaging and clinical cases helped students in these first two domains, i.e., with recollection and recognition of the material and with comprehension, organisation and interpretation. Its effect on student performance might begin to plateau by the third level, which involves the application of gained knowledge to solve problems or use them in different scenarios. That might be for instance, dependent on students' independent study after classes, their previous knowledge from earlier semesters and their personal situations.

In summary, the effect that the integrated course had on student performance can be observed by the mean score of total achieved points by group, demonstrating that the mean score for the intervention group was 20.92 points and the mean score of the control group was 19.42 points out of a total of 37 points. This means that the average student that was exposed to imaging and clinical cases scored 1.5 points more, around 2.5% better than without attending the intervention.

The difference was small and did not show statistical significance $p=0.16$. Nevertheless, the result on the performance assessment was numerically higher and could be indicative of a trend, especially since this favourable outcome has been studied and recorded with medical students (Chew et al., 2020, Paech et al., 2017, Paech et al., 2018, Webb and Choi, 2014). This trend would have to be studied on a larger scale (for more on sample size as a weakness of this study, See Section 4.3.). Our results also indicate that the highest areas of improvement of performance are on the first two levels of Bloom's taxonomy.

4.2 Student motivation

4.2.1 Key findings

The effect of the integrated curriculum on student motivation was measured with the student feedback survey. Here, students repeatedly valued various aspects of the integrated curriculum as above average and as a considerably important supplement to their education, whereas a certain disdain towards having radiology as a standalone subject in preclinical years was noticeable. After participating in the intervention, students assessed their own knowledge gains across their desired learning objectives, showing substantial learning achievements overall, albeit with some variation of confidence in the learning displayed amongst the desired learning objectives. This intervention was awarded a high level of enjoyment by students, who by a substantial majority, also recommended that the course be introduced into other preclinical semesters. Their perspectives on an integrated teaching approach of anatomy and radiology are depicted in Figure 13.

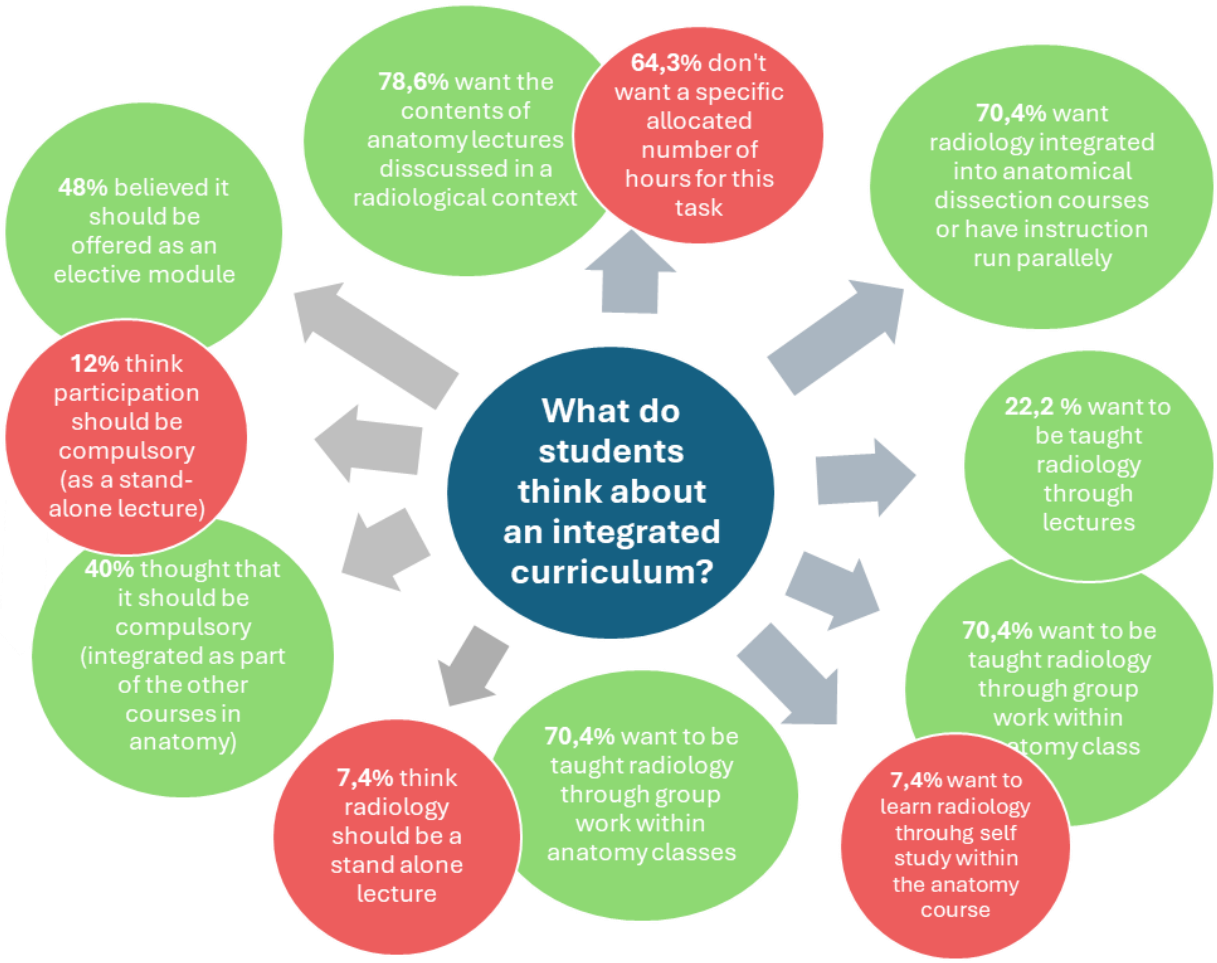

Figure 13 Students' perceptions of the integrated curriculum

4.2.2 Interpretations and implications

A clear success from this intervention was, in line with the hypothesis, a well registered interest of the student body towards the integrated curriculum. This result is supported by existing research on medical students (Marker et al., 2010, Dettmer et al., 2013, Murphy et al., 2015). Students largely reported wanting the contents of anatomy lectures discussed in a radiological context every semester (78.6%) and thought it to be advantageous for their education altogether (mean 7.56) and specifically for their anatomy course (mean 6.96). Not only did students attribute an above average importance towards the integrated teaching of radiology and anatomy (mean 7.46) but they also reported a high level of enjoyment (mean 8.07) with the integrated curriculum after participating in it. Notably 78.6% recommended that the integrated curriculum should also be offered in the second preclinical semester, one semester earlier than when they had experienced it in the third semester.

On the portion of the survey where students evaluated the course, all means lay well above the midpoint of 5, and even though the results throughout the 3 Likert scales were spread between 2-10, there were very few responses under 4 (n=2). These results indicate a positive perception of students regarding the course they attended.

Reported learning outcomes by students were an improvement of knowledge of the topographical relationships of the structures within the head and neck area, as well as a better understanding of difficult anatomical structures and their relationship to each other through the help of three-dimensional imaging. The results of attending the course were declared to be an increased enthusiasm for the subject of anatomy as well as an expansion of knowledge in the subject. When considering the complete scope of the self-assessed learning outcomes, most mean scores exceeded 7, which presents a positive marker for successful acquisition of knowledge by students. Three objectives fell under this threshold at 6.5, 6 and 5.43, indicating areas for potential improvement of instruction, as discussed below. The perceived importance of this integrated approach towards their overall education strongly corelated in a positive manner with increased self-evaluated gained knowledge ($r=0.76$, $p<0.001$), highlighting that the contents of the course resonate well with students and that there is appreciation for its future relevance for their education.

A factor to explore when analysing student satisfaction and motivation regarding this course is the role that radiology plays for students as a standalone subject in preclinical

years, moving beyond it solely being integrated into another subject. There have been calls for an early, preclinical exposure of medical students to radiology (Oris et al., 2012, Barton F. Branstetter, 2008, Mirsadraee et al., 2012). However, the outcomes of the student survey point to a certain lack of interest towards radiology as a standalone subject. Students attributed an above average relevance to the teaching of basic radiology in the preclinical phase of their studies, but notwithstanding this, when asked about the format for bringing the subject into preclinical years, 92.6% of participants chose options where it would be integrated into anatomy (lectures and dissection courses), reporting essentially no interest in it being offered as a separate course of seminars or lectures (7.4%). The trend of radiology being perceived by students as a mere complement to their anatomy education has been seen in other studies (Murphy et al., 2015), and although this complement is seen as useful, students disagreed about it being the sole method for anatomy instruction (Murphy et al., 2015). Notable limitations towards using radiology as the sole approach have also been discussed (Aziz et al., 2002, Gunderman and Wilson, 2005), emphasizing that cadaveric dissection should remain at the core of instruction.

In our survey, students further specified that they would want to be taught radiology by means of group work within anatomy classes (70.4%) as opposed to lectures or self-study. Though there was generally support for the idea of having it as an elective course for preclinical years (48%), very few agreed with radiology being a compulsory stand-alone course, and much more support was seen for compulsory attendance within the framework of anatomy courses (40%). Amongst students' opinions, there was only a moderate correlation between their assessment of the importance of integrated teaching of anatomy and radiology and the recognized importance of radiological teaching in preclinical years, further painting the picture that it might not be in student interest to have radiology brought into preclinical years as a stand-alone course.

The desired learning objectives that related directly to the radiology portion of the course were "I can differentiate between different imaging methods" and "I can orientate myself within an CT/CBCT/MRI/X-ray image," that students reported as having acquired, with means of 7.4 and 7.2, respectively. However, students reported less learning confidence in "I understand the basic mechanism of CT/CBCT/MRI/ X-ray imaging methods," which reflects a foundational ILO of any radiology course. The conceptualized course allocated instructional time towards this (albeit in a simplified form), but based on the student's self-

perceived learning, it was not established as one of the biggest areas of knowledge acquisition and should be considered for future cohorts.

Given that radiology is by its nature a clinically loaded subject, the integration of it into anatomy teaching sought to also open the door to the clinical relevance of the studied materials to students, who had to actively apply their acquired knowledge in anatomy and radiology to solve clinical cases. This is thought to boost student interest and motivation (Collins, 2009). Even though these cases were adapted to best fit students existing level of knowledge and relevant clinical context was provided, it can be inferred that they might have had difficulties effectively transferring knowledge in a clinical context. The desired learning outcome with the lowest mean (5.43) was “I can recognize whether radiological images of the head and neck region are physiological or pathological” demonstrating a slight deficiency; however, students still specified an increased enthusiasm for the subject of anatomy and a simultaneous expansion of anatomical knowledge due to this clinical context (means of 7.25 and 7.21, respectively).

Case-based or case-oriented anatomy teaching is thought to increase student enthusiasm and is often encouraged to be implemented into anatomy teaching (Chytas et al., 2021). Notwithstanding that as a cohort they agreed in having gained an insight into various clinical conditions (median 7), a high IQR (IQR:6-10) suggests a bigger discrepancy in opinions. Although the regarded importance of covering clinical cases in the integrated course recorded a mean of 6.96, the overall usefulness of these clinical cases for students’ education was already recognized at a higher value (7.56). There was virtually no desire to incorporate more clinical cases into the course (10.7%), and most (82.1%) found 6 cases to have been enough for one semester. Additionally, it is notable that half of the participants desired more time to focus on normal anatomical findings on CT/MRI/X-ray images, so that when considering how to optimize instruction for future cohorts this should be taken into account.

The effect that the integrated approach had on student motivation was overall positive and in line with the observed effects on medical students. Students were in favour of the integration and wanted to have it available in other semesters. They valued the integration as an important addition to their education and it led them to feel more knowledgeable. The survey collected valuable insights regarding students’ desired format of integration, which is helpful when further optimizing instructional methods.

4.3 Strengths and limitations

This study was a pilot project at Charité, and as such, it was in its nature to test out the conceptualized curriculum.

One great strength which was detected is the sustainability of the project, as this has been a concern for integrated curricula, especially when considering the extraordinary costs or time invested by instructors (Dettmer et al., 2013, Chew et al., 2020, Phillips et al., 2013). In contrast to the many attempts to pursue this educational approach as an elective or new stand-alone module (Dettmer et al., 2013, Murakami et al., 2014) it is important to find cost-effective ways of integration that do not disrupt standing lectures and seminars. This was also what Wilson et al. (2018) called for, while seamlessly incorporating the integrated teaching into the standing curriculum (Wilson et al., 2018). We adopted the same approach in this study; the only extra activity that arose was the one-time creation of the instructional units (which can be reused every semester) and copies of the exercise sheets for students. No further materials were physically needed, and our team reported no shortage of them (it is, however, important to mention that students brought their own laptops or tablets). This generated almost no additional costs for the institution, greatly differing from approaches where elective modules are created, and we established a foundation for the course to be offered consistently every following semester. Consequently, we demonstrated that institutions wanting to explore this integrated teaching approach have a format which they can commit to with less difficulty and constraints vis-à-vis budget, personnel or required facilities/rooms/lecture halls. While admitting that computer and/or web-based programs and modules are also an available and cost-effective way to integrate the subjects (Marker et al., 2010, Webb and Choi, 2014), nevertheless, students profit from student to teacher interactions in this subject (Dettmer et al., 2013), an also in general, when learning new concepts or skills (Paechter and Maier, 2010), so that these formats are perhaps not the most ideal approaches.

Although some believe that this could also be a beneficial approach for dental students to learn anatomy (McHanwell, 2015), this study is, to the best of our knowledge, the first to implement an integrated teaching of gross anatomy and radiology in preclinical years specifically with dental students.

We argue that this aspect is a very relevant consideration for, and addition to current research, as dental students have a significantly different relationship with the subject of radiology. All dentists must be well-versed in radiology and use it as a diagnostic tool daily, but do not have access to it as a specialty. To achieve an in-depth understanding of the subject or improve students' enthusiasm are not the main concerns for this cohort, contrary to research on medical students, where these aspects are of greater value (Hattam, 2013, Barton F. Branstetter, 2008, Branstetter et al., 2007). Our findings suggest that dental students do not view radiology as a standalone subject in preclinical years with significant interest. This may justify why, for this type of cohort, it is acceptable to conduct the course without a dedicated radiologist, going against recommendations for these programs when targeted at medical students (Wilson et al., 2018, Phillips et al., 2013, O'Keeffe et al., 2019), and using radiology primarily as a tool to enhance their understanding of anatomy.

To the best of our knowledge, this is also the first study that attempts to exactly understand how the improvement in student performance occurs from an integration like this. This was done by assessing how results in performance differ when considering different levels of cognitive demand.

Where limitations are observed, are, for one, in sample sizing and statistical power. Due to a low sample size, it is necessary that these findings are interpreted with care and can only be directly applied to this specific cohort. Therefore, some associations may be weighted differently in other datasets or larger cohorts.

Another limitation would be that this was a non-blinded study. The intervention group was informed of their group assignment and were given a summary of the study. Therefore, participants knew that they would be participating in a modified curriculum in comparison to their peers. Given that the intervention was integrated into a compulsory module, there was no ethical or practical way to mask this information from the intervention group, since the rest of the semester would have different classes running parallelly, even within the same facility (the dissection lab).

The last limitation of this study involves the assessment format. To minimize potential biases and to enable standardized scoring, the examination format was changed from the usual oral exam with a pass or fail system that our institution has for the subject of anatomy to a written examination with a cumulative point score. Here a testing modality

bias could be argued, as students are unaccustomed to this format of assessment. Consequently, their usual exam-taking strategies, developed through their exposure to previous tests in anatomy classes, may prove ineffective in this context, which could have potential influence on their performance. However, this bias was considered negligible since it affected both the intervention and control group to the same extent and the comparison in performance was deemed as a valid for the intervention's effect on student performance.

4.4 Future directions

This study did not demonstrate a statistically significant improvement on the assessment form but revealed high levels of enthusiasm amongst students for the integrated approach. Given that that was the measurable success of the intervention, it might be valuable to determine whether students preferred this way of teaching to the traditional approach at our institution. Although not directly examined in this study, the answer can be inferred based on students' responses regarding their desire for the integrated curriculum to also be integrated into earlier semesters.

With this in mind, and students' responses to the survey, adjustments to the course conception would be encouraged, so that:

- the foundations of imaging are described to a fuller extent
- an increased amount of time is given to students for them to get familiar with normal anatomy on three-dimensional imaging
- the integration is extended into all preclinical anatomy modules
- clinical cases are reduced and/or more closely targeted to dentistry and dental related diseases and conditions
    - For instance, during the modules where skull, head and neck anatomy are studied there would be a higher number of clinical cases, and during the study of extremities, the thorax, the digestive track, etc., there would be less, while utilizing normal imaging just as a tool to foster anatomical knowledge. This adjustment could enhance the perceived relevance of the material, without overwhelming students, which might transpire if they are confronted with an abundance of clinical cases from anatomical regions where only a rudimentary understanding of anatomy is needed, such as the respiratory system.

Further research is needed to validate the findings of this study, and by extending the integrated approach to all preclinical semesters, a bigger sample size could be generated. Additional studies are encouraged to explore how the integrated teaching of radiology in preclinical anatomy education can specifically aid dental students, and so that its effect is more comprehensively understood. This study shows suggestive evidence for a possible difference between how radiology might aid anatomy teaching for dental students in comparison to medical students. Students displayed little interest in having more radiological input, and it can be assumed that radiology's primary role within preclinical dental education has a bigger focus on being an aid for anatomy instruction, rather than fostering interest for the speciality and generating a connection to clinical relevance.

The central question concerning the future of anatomy education is not resolved by this study. The answer is likely to vary based on institutional priorities and student needs. However, what is unmistakably clear is that anatomy education is undergoing a transition. The significance of anatomy within preclinical curricula remains undisputed, yet a clear trend shows a reduction in the time dedicated to it (Tibrewal, 2006, Collins et al., 1994, Drake et al., 2009). This shift is evident even in the context of this study, where by the end of the intervention, new regulations have reduced anatomy instruction by an entire semester for German universities.

A central question currently revolves around whether cadaveric dissection should be abandoned. Many argue against this, advocating instead for an enhancement of student enjoyment of the courses.

Combined with the call for earlier exposure to radiology and the increasingly significant role that radiology plays for dental students - along with the positive reception from our cohort - this suggests that integrating radiology into the dental preclinical anatomy curriculum is the optimal approach for this group of students. Considering the concerns about students' anatomical knowledge being insufficient (Lockwood and Roberts, 2007, Older, 2004, Pryde and Black, 2005), it is especially encouraging that this method has been shown to have a positive effect on performance.

5 Conclusion

Preclinical curricula in medical and dental education are increasingly saturated with other basic sciences, and while the relevance of anatomy remains unquestioned, it must adapt to contemporary teaching and curricula changes. This is especially important when considering the reported decline of anatomical knowledge amongst students.

As corroborated by numerous studies, there seems to be great potential in integrating radiographic imaging to boost interest and motivation, and to support a three-dimensional understanding of anatomy.

While the current body of research has only focused on medical students, this study has focused on dentistry students. The results highlight the effect of an integrated teaching approach combining radiology with standing anatomical cadaveric dissection, namely, high levels of satisfaction and perceived importance. Students largely indicated wanting the contents of anatomy lectures discussed in a radiological context every semester and thought it to be advantageous for their education altogether. They recognized the integrated approach for an increased level of knowledge in gross anatomy and radiology.

Moreover, a positive impact on student performance was observed, especially in lower domains of cognitive demand, that must be validated through further research on larger cohorts.

The methods used to create an integrated approach in this study can assist other institutions and educators in developing an integrated curriculum with minimal time and cost as well as help address the gap created by the shortage of instruction time, while improving students' knowledge of anatomy.

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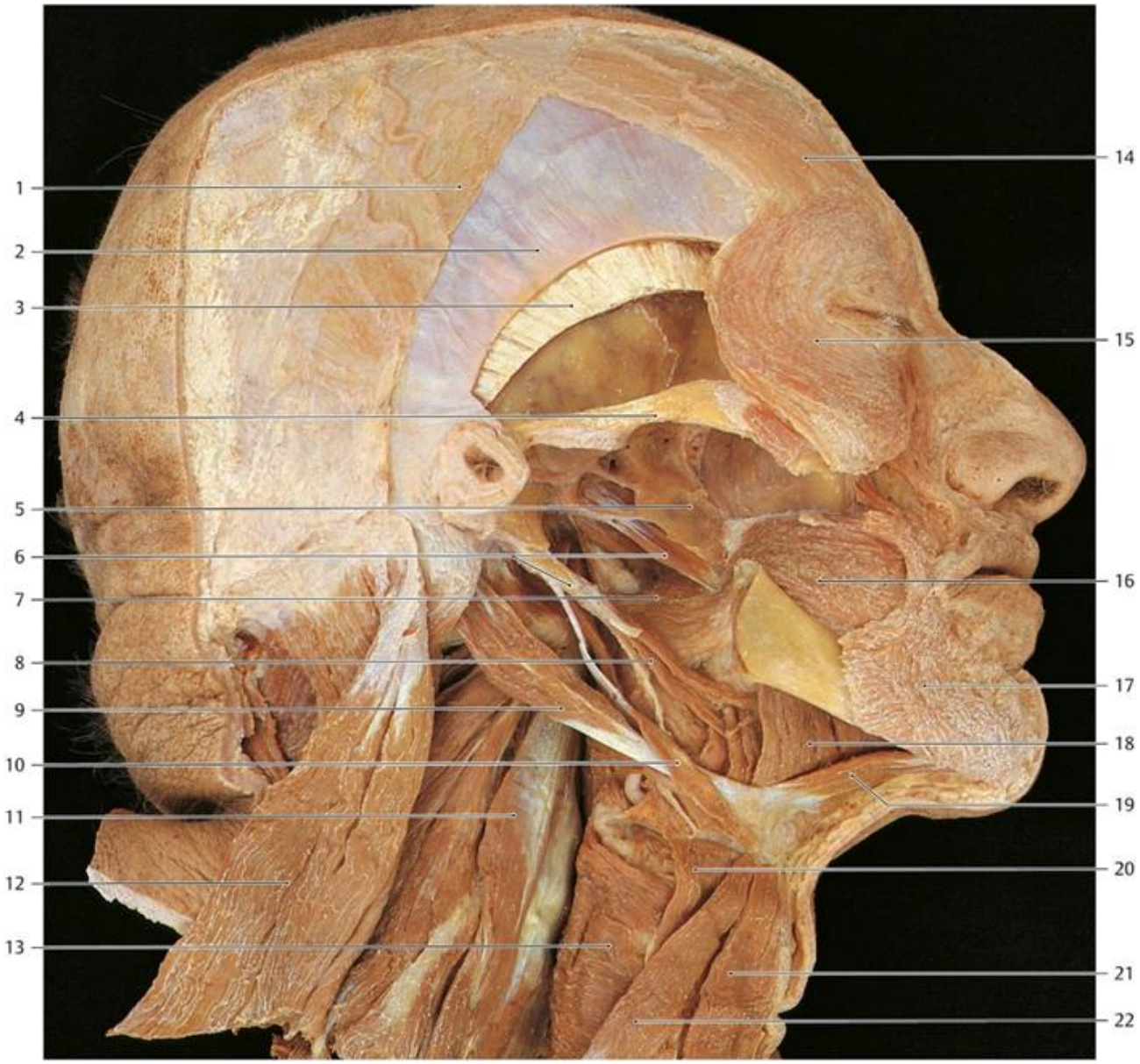
Appendix A

Student Assessment Form

Waren Sie im Präparierkurs in der Gruppe von [redacted]? ☐ ja ☐ nein

1. Beschriften sie in der folgenden Abbildung die Punkte 1-22.



1.	2.
3.	4.
5.	6.
7.	8.
9.	10.
11.	12.
13.	14.
15.	16.
17.	18.
19.	20.
21.	22.

2. Die Fossa pterygopalatina ist durch verschiedene Strukturen mit anderen Teilen des Schädels verbunden. Vervollständigen Sie dazu folgende Tabelle:

Öffnung	Ziel
Foramen rotundum	
	Fossa infratemporalis
Foramen sphenopalatinum	
	Orbita
Foramen palatinum majus und Foramina palatina minora	
	Basis cranii externa

3. Der Nervus trigeminus teilt sich in drei Hauptäste auf. Bennen Sie diese sowie deren Durchtrittstelle durch die Schädelbasis, und wo sie hineinmünden.

Name	Durchtritt durch die Schädelbasis	wo sie hineinmünden
V1:		
V2:		
V3:		

4. Welche Aussage zur Kaumuskulatur trifft zu?

a. Der M. masseter setzt am Angulus mandibulae an und wird motorisch von dem N. facialis innerviert.
b. Der M. pterygoideus lateralis Caput superius hat seinen Ursprung in der Fossa pterygoidea und führt bei beidseitiger Kontraktion zur Protrusion der Mandibula.
c. Der M. pterygoideus lateralis Caput inferius setzt am Proc. condylaris der Mandibula an und wird vom N. mandibularis innerviert.
d. Die Kontraktion des M. temporalis führt zur Kieferöffnung und zur Protrusion der Mandibula.
e. Die Kieferöffnung erfolgt durch den M. pterygoideus lateralis und die infrahyoidale Muskulatur.

5. Welche Aussage zum N. facialis ist richtig?

a. Die nichtmotorischen Fasern aus dem Ncl. tractus solitarii und Ncl. nervi abducentis bilden zusammen den N. intermedius.
b. Die Fasern des N. intermedius lagern sich den motorischen Fasern des Nervus facialis an. Gemeinsam mit einigen Trigeminusfaser verlassen sie alle die Schädelbasis am Foramen stylomastoideum.
c. Die Schädigung des N. facialis im Canalis facialis in der Nachbarschaft des Canaliculus chordae tympani kann zu Geschmacks- und Speichelsekretionsstörungen führen, sowie zur peripheren Lähmung der mimischen Muskulatur.
d. Die gustatorischen Fasern (speziell viszeroafferent) des Nervus facialis innervieren das hintere Drittel der Zunge.
e. Nach Umschaltung der parasympathischen Fasern der Chorda tympani im Ganglion pterygopalatinum ziehen die postganglionäre Fasern zu den Speicheldrüsen.

6. Welche Aussage zu den Strukturen der Mundhöhle trifft zu?

a. Die Glandula parotidea ist eine rein seröse Drüse. Ihr Ausführungsgang verläuft oberhalb des M. masseter, durchbricht den M. buccinator, und mündet in der Unterkiefer Prämolarenregion in die Mundhöhle ein.

b. Zu der äußeren Zungenmuskulatur zählen M. styloglossus, M. hyoglossus und M. geniohyoideus. Sie werden von den N. hypoglossus innerviert.

c. Die Zähne im Ober- und Unterkiefer werden von dem dritten Trigeminusast innerviert.

d. Der harte Gaumen wird aus 3 knöchernen Strukturen gebildet: Os palatinum, Os incisivum, Os maxillare.

e. Maxilla, Mandibula und Os palatinum entwickeln sich aus den Anlagen des 2. Schlundbogens.

Appendix B

Student Feedback survey

Fragebogen zur Evaluation der Zufriedenheit mit den klinisch-radiologischen Fallbeispielen im Verlauf des Kurses

Liebe Studierende,

Um ihre Zufriedenheit mit den klinischen Inhalten und den besprochenen radiologischen Fällen im Verlauf ihres Präparierkurses zu erfassen, finden sie im Folgenden eine kurze Umfrage. Wir möchten Sie herzlich einladen, sich an der Evaluation zu beteiligen. Die Teilnahme an der Umfrage ist freiwillig und die Ergebnisse der Befragung sind anonym, sodass keine Rückschlüsse auf ihre Person möglich sind.

1. Epidemiologische Daten

1. 1 Alter:
1. 2 Geschlecht:

□ männlich
□ weiblich
□ divers / nicht binär

1. 3 Haben Sie vor / neben Ihrem Zahnmedizinstudium Wissen in Zahn- oder Humanmedizinischen Fächern erworben?

Ja

□ eine Ausbildung in einen Gesundheitsberuf angefangen/ abgeschlossen
□ ein Studium in der Humanmedizin angefangen/ abgeschlossen
□ in einer Praxis/ Klinikum gearbeitet
□ andere: _____

Nein □

2. Fragen zur integrierten Lehre von Anatomie und Radiologie

1. Wie wichtig empfinden Sie die integrierte Lehre von Radiologie und Anatomie?

Nicht wichtig (1) 1 2 3 4 5 6 7 8 9 10 *Sehr wichtig (10)*

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

2. Wie wichtig empfinden Sie die Lehre von radiologischen Grundzügen bereits in der Vorklinik?

Nicht wichtig (1) 1 2 3 4 5 6 7 8 9 10 *Sehr wichtig (10)*

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

3. Würden Sie sich wünschen, dass jedes Semester die Themen der Anatomie Vorlesung auch im radiologischen Kontext besprochen würden?
   □ Ja □ Nein

4. Hätten Sie sich gewünscht, dass in den Anatomie Vorlesungen eine bestimmte Stundenanzahl für die Besprechung der Thematik im radiologischen Kontext reserviert werden sollte?

   □ Ja □ Nein

   4.1 Wenn ja, wie viele Stunden? _____

5. In welchem Format würden Sie die Lehre der Radiologie bevorzugen:
   □ Vorlesung (Lehrendenvortrag)
   □ Gruppenarbeit im Anatomiekurs
   □ Selbststudium im Anatomiekurs

6. In welchem Kontext würden Sie sich die Integration von Radiologie in der vorklinischen Lehre der Anatomie wünschen?
   □ in den Vorlesungen, immer begleitend zu den behandelten Themen
   □ parallel/ begleitend zum Präparierkurs
   □ separat, als alleinstehendes Seminar/ Vorlesungsreihe

7. Die vorklinische Lehre von Radiologie sollte….
   □ Pflicht sein (Integriert als Teil der anderen Pflichtveranstaltungen im Fach Anatomie)
   □ Pflicht sein (als alleinstehende Veranstaltung)
   □ Als Wahlmodul angeboten werden

3.Bewerten Sie folgende Aussagen

Nach dem Besprechen der radiologischen und klinischen Fallbeispiele

	Stimme ich nicht zu (1)	1	2	3	4	5	6	7	8	9	10	*Stimme ich zu (10)*
… kann ich verschiedene Methoden in der Bildgebung differenzieren		□	□	□	□	□	□	□	□	□	□	
… verstehe ich den Grundmechanismus der CT/DVT/MRT/klassisches Röntgen Aufnahmemethoden		□	□	□	□	□	□	□	□	□	□	
… kann ich mich innerhalb eines Röntgen / CT / MRT Bildes orientieren		□	□	□	□	□	□	□	□	□	□	
… habe ich meine Kenntnisse über die Topographischen Verhältnisse der anatomischen Strukturen im Kopf-Hals Bereich verbessert		□	□	□	□	□	□	□	□	□	□	

	Stimme ich nicht zu (1)	1	2	3	4	5	6	7	8	9	10	*Stimme ich zu (10)*
… habe ich mithilfe der dreidimensionalen Bildgebung schwierige anatomische Strukturen und deren Beziehung zueinander besser verstanden		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
… hat sich aufgrund der klinischen Bezüge meine Begeisterung für das Fach Anatomie erhöht		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
… habe ich meine Anatomiekenntnisse ausbauen können, da ich sie in einem klinischen Kontext anwenden musste		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
… erkenne ich auf radiologischen Bildern der Kopf-Hals Region, ob diese physiologisch oder pathologisch sind		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
… habe ich einen Einblick in verschiedene Erkrankungen, die den Kopf-Hals Bereich betreffen, bekommen		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

4.Fragen zum Kurs

4.1 Der Kurs bestand insgesamt aus 6 Fallbeispielen, die in den Anatomiekurs integriert wurden. Ihrer Meinung nach sollte dieser Kurs aus….

☐ weniger Fallbeispiele pro Semester bestehen

☐ genauso vielen Fallbeispielen pro Semester bestehen

☐ mehr Fallbeispiele pro Semester bestehen

4.2 Wie wichtig empfanden Sie die Behandlung klinisch/ radiologischer Fälle im Kurs?

Nicht wichtig (1)	1	2	3	4	5	6	7	8	9	10	*Sehr wichtig (10)*
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

4.3 Hätten Sie lieber mehr Zeit damit verbracht, sich mit normalanatomischen CT/MRT/Röntgenbildern auseinanderzusetzen?

□ Ja □ Nein

4.4 Würden Sie eine Integration radiologischer Fallbeispiele auch in den Anatomiekurs des 2. Semesters befürworten?

□ Ja □ Nein

4.5 Wie sinnvoll für ihre Ausbildung empfanden Sie die Integration der klinisch/ radiologischen Fallbeispiele?

Nicht sinnvoll (1) 1 2 3 4 5 6 7 8 9 10 *Sehr sinnvoll (10)*

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

4.6 Wie sehr hat Ihnen die Integration der klinisch/ radiologischen Fallbeispiele gefallen?

Nicht gefallen (1) 1 2 3 4 5 6 7 8 9 10 *Sehr gut gefallen (10)*

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Eidesstattliche Versicherung

„Ich, Victoria Pereira Vertic, versichere an Eides statt durch meine eigenhändige Unterschrift, dass ich die vorgelegte Dissertation mit dem Thema: „*Effects of the course "Clinical Anatomical Imaging of the Head for Dental Students" as part of preclinical anatomy education on student performance and motivation*“, „*Auswirkungen des Kurses „Klinisch-anatomische Bildgebung des Kopfes für Zahnmedizinstudierende“ auf Leistung und Motivation im vorklinischen Anatomieunterricht*“, selbstständig und ohne nicht offengelegte Hilfe Dritter verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel genutzt habe.

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Ich versichere ferner, dass ich die in Zusammenarbeit mit anderen Personen generierten Daten, Datenauswertungen und Schlussfolgerungen korrekt gekennzeichnet und meinen eigenen Beitrag sowie die Beiträge anderer Personen korrekt kenntlich gemacht habe (siehe Anteilserklärung). Texte oder Textteile, die gemeinsam mit anderen erstellt oder verwendet wurden, habe ich korrekt kenntlich gemacht.

Meine Anteile an etwaigen Publikationen zu dieser Dissertation entsprechen denen, die in der untenstehenden gemeinsamen Erklärung mit dem/der Erstbetreuer/in, angegeben sind. Für sämtliche im Rahmen der Dissertation entstandenen Publikationen wurden die Richtlinien des ICMJE (International Committee of Medical Journal Editors; www.icmje.og) zur Autorenschaft eingehalten. Ich erkläre ferner, dass ich mich zur Einhaltung der Satzung der Charité – Universitätsmedizin Berlin zur Sicherung Guter Wissenschaftlicher Praxis verpflichte.

Weiterhin versichere ich, dass ich diese Dissertation weder in gleicher noch in ähnlicher Form bereits an einer anderen Fakultät eingereicht habe.

Die Bedeutung dieser eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unwahren eidesstattlichen Versicherung (§§156, 161 des Strafgesetzbuches) sind mir bekannt und bewusst.“

Datum	Unterschrift

Curriculum Vitae

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

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