Medical University
"Prof. Dr. Paraskev Stoyanov" – Varna

Sliven Affiliate
Department of Healthcare

Elka Dancheva Kostova

MODERN COMPETENCIES OF THE X-RAY LABORATORY ASSISTANT IN DENTAL DIGITAL DIAGNOSTIC IMAGING

THESIS SUMMARY

Of a PhD Thesis
For awarding the educational and scientific degree of
Philosophy Doctor
In the field of higher education, 7. Healthcare and Sports
Professional area 7.4. Public Health
Scientific speciality: Healthcare Management

Research Supervisor:

Assoc. Prof. Svetlana Peneva Angelova, PhD

Sliven, 2026

The doctoral thesis is presented on 178 pages and is structured in five main chapters. It includes 67 figures, 14 tables, and 5 appendices. The bibliography features an extensive list of 232 sources, of which 36 are in Cyrillic and 196 in Latin.

Scientific Jury

1. Prof. Maya Lyubomirova Viseva, PhD
2. Prof. Galina Stamova Chaneva, PhD
3. Assoc. Prof. Pavlina Penkova Teneva, PhD
4. Assoc. Prof. Pepa Miteva Dzhedzheva, PhD
5. Assoc. Prof. Silviya Ivanova Filkova, PhD

The doctoral thesis was discussed and referred for defence by an expanded departmental council of the Department of Healthcare, Sliven Affiliate of the Medical University "Prof. Dr. P. Stoyanov" – Varna, on 24/02/2026.

The online doctoral defence is scheduled for 08/05/2026, and will be hosted on the Webex virtual platform of the Medical University – Varna, at an open session of the Scientific Jury.

The defence documentation is available at the Scientific Department of Medical University – Varna and is published on www.mu-varna.bg.

Note: In the thesis summary, the numbering of figures and tables does not correspond to that in the doctoral thesis.

CONTENTS

LIST OF ABBREVIATIONS

BAHP	Bulgarian Association of Healthcare Professionals
BARIDAT	Bulgarian Association of the Radiographers in Image Diagnostics and Therapy
USR	Ordinance on Unified State Requirements
AI	Artificial Intelligence
CT	Computed Tomography
REC	Research Ethics Committee
MHAT	Multi-profile Hospital for Active Treatment
MU	Medical University
NCRRP	National Centre of Radiobiology and Radiation Protection
PGT	Postgraduate Training
EC	Elective Course
UMHAT	University Multi-profile Hospital for Active Treatment
AC	Academic Council
2D/3D	Two-dimensional / Three-dimensional imaging
CBCT	Cone Beam Computed Tomography
DICOM	Digital Imaging and Communications in Medicine (Standard file format for medical images)
JPEG	Digital image format
PACS	Picture Archiving and Communication System
TIFF	Tagged Image File Format (high-quality raster image format)

INTRODUCTION

Dental diagnostic imaging is a fundamental tool for treatment planning and monitoring outcomes in various clinical issues related to the oral cavity and surrounding tissues. Radiographs (X-rays) are mandatory for establishing a correct diagnosis and objectively evaluating the stages of treatment.

Digitalisation in healthcare has changed the roles and responsibilities of health professionals. Rapidly evolving technologies have increased the frequency with which they have to update their competencies in order to provide adequate care. It is the responsibility of X-ray laboratory assistants to obtain accurate images and to apply dose optimisation approaches when using diagnostic imaging methods.

This requires additional competencies that correspond to the enormous technological advances in medical imaging.

Our aim is to analyse the contemporary proficiencies of the X-ray laboratory assistant in working with dental imaging diagnostics. We aim to formulate guidelines for broadening their expertise in the context of the global advance of digitalisation and artificial intelligence. The lack of prior research on this issue motivated the present study. We believe that analysing the research results and developing and introducing the elective course "Dental Digital Imaging Diagnostics" will contribute to optimising the training of X-ray laboratory assistants.

I. METHODOLOGY OF THE DOCTORAL THESIS

1.1. Aim and Objectives of the Study

Aim: To analyse the contemporary competencies of X-ray laboratory assistants in dental imaging diagnostics, to formulate guidelines for their expansion in response to the global shift toward digitalisation and artificial intelligence.

To achieve this aim, the following **tasks** were set:

1. To investigate and analyse the available domestic and foreign literature on the studied problem over the past five years.
2. To conduct a comparative analysis of the imaging methods used in dental diagnostics.
3. To identify the key areas of competencies of X-ray laboratory assistants (X-ray technicians) regarding the use of digital technologies in practice.
4. To explore the opinions of lecturers on special subjects, students, practising X-ray technicians, and employers regarding the relevance of the professional knowledge and skills acquired, and the extent to which graduates are ready for hands-on clinical work in dental practice.
5. To establish the attitudes of lecturers, students in the speciality, and practising X-ray technicians toward additional training aimed at expanding competencies in dental digital imaging diagnostics.
6. To investigate the opinions of experts in Radiology and Dental Medicine regarding the competencies of X-ray laboratory assistants in dental imaging diagnostics.
7. To determine the need for developing and introducing an elective course that will expand the competencies of X-ray laboratory assistants in the field of dental imaging diagnostics.

1.2. Research Hypotheses

1. The assumption is that the current professional competencies of X-ray laboratory assistants in the field of dental imaging diagnostics do not sufficiently correspond to the modern pace of developments in the profession, in view of healthcare digitalisation.
2. The assumption is that a significant share of respondents will express a positive attitude toward additional training aimed at improving training for working in the field of dental digital imaging diagnostics.
3. The assumption is that the development and introduction of an elective course in the training of students in the speciality is a tool for expanding their professional competencies to better adapt to new demands.

1.3. Subject, Object, and Organisation of the Study

Subject of the study: The modern competencies of the X-ray laboratory assistant in working with dental digital imaging diagnostic equipment.

Objects of the study:

- Lecturers from the Medical colleges in the country;
- Students in the X-ray Laboratory Assistant speciality;
- Practising X-ray laboratory assistants (X-ray technicians);
- Employers of X-ray Laboratory Assistant speciality graduates;
- Experts in Radiology and Dental Medicine.

Scope of the study

The study population consists of 317 participants, distributed as follows:

- Lecturers delivering special subjects in the X-ray Laboratory Assistant speciality at the Medical College "Y. Filaretova" – Sofia, Medical College – Plovdiv, Medical College – Varna, and Medical College – Pleven — (n=24)
- Students in the X-ray Laboratory Assistant speciality at the Medical College "Y. Filaretova" – Sofia, Medical College – Plovdiv, Medical College – Varna, and Medical College – Pleven — (n=127)
- Practising X-ray technicians in the cities of Varna, Dobrich, Shumen, Veliki Preslav, and Omurtag — (n=113)
- Employers of X-ray Laboratory Assistant speciality graduates in the cities of Varna, Dobrich, Shumen, Veliki Preslav, and Omurtag — (n=46)
- Experts in Radiology and Dental Medicine — (n=7)

Logical units of the study and criteria for inclusion and exclusion:

First logical unit of respondents – every lecturer in special subjects in the X-ray Laboratory Assistant speciality at the Medical Colleges in Sofia, Plovdiv, Varna, and Pleven.

Criteria for inclusion:

- More than 1 year of professional experience;
- Provided written consent for participation in the study.

Criteria for exclusion:

- Lecturing in other subjects;
- Less than 1 year of professional experience;
- Did not provide written consent for participation in the study.

Second logical unit of respondents – every student enrolled in the X-ray Laboratory Assistant speciality at the Medical College – Sofia, Medical College – Plovdiv, Medical College – Varna, and Medical College – Pleven.

Criteria for inclusion:

- Full-time students in the X-ray Laboratory Assistant speciality at the Medical Colleges in Sofia, Plovdiv, Varna, and Pleven;
- Provided written consent for participation in the study.

Criteria for exclusion:

- Students of other specialities at the Medical Colleges in Sofia, Plovdiv, Varna, and Pleven;
- Did not provide written consent for participation in the study.

Third logical unit of respondents – every practising X-ray technician in the cities of Varna, Dobrich, Shumen, Veliki Preslav, and Omurtag.

Criteria for inclusion:

- Practising X-ray technicians in inpatient and outpatient healthcare facilities with imaging diagnostics departments/units/centres in Varna, Dobrich, Shumen, Veliki Preslav, and Omurtag;
- More than 1 year of professional experience;
- Provided written consent for participation in the study.

Criteria for exclusion:

- X-ray technicians practising in other settings;
- Less than 1 year of professional experience;
- Did not provide written consent for participation in the study.

Fourth logical unit of respondents – every employer of the X-ray Laboratory Assistant speciality graduates in the cities of Varna, Dobrich, Shumen, Veliki Preslav, and Omurtag.

Criteria for inclusion:

- Employers of X-ray laboratory assistants in inpatient and outpatient healthcare facilities with imaging diagnostics departments/units/centres in Varna, Dobrich, Shumen, Veliki Preslav, and Omurtag;

- More than 1 year of professional experience;
- Provided written consent for participation in the study.

Criteria for exclusion:

- Employers of X-ray technicians from other healthcare facilities/other settings;
- Less than 1 year of professional experience;
- Did not provide written consent for participation in the study.

Fifth logical unit of respondents – every expert in Radiology and Dental Medicine in the city of Varna.

Criteria for inclusion:

- Established specialists in the fields of Radiology and Dental Medicine in Varna;
- Provided written consent for participation in the study.

Criteria for exclusion:

- Did not provide written consent for participation in the study.

Time and place of the study

The study lasted three years. It started after receiving approval from the Ethics Research Committee of the Medical University – Varna, with Decision No. 3/02.08.2024. The main research was conducted during the period August – November 2024, supplemented in January – March 2025, after securing signed agreements from the Directors of the Medical Colleges and the managers of the healthcare facilities.

The study was conducted at the Medical College – Sofia, Medical College – Plovdiv, Medical College – Varna, and Medical College – Pleven, as well as in inpatient and outpatient healthcare facilities with imaging diagnostics departments, units, or centres in the cities of Varna, Dobrich, Shumen, Veliki Preslav, and Omurtag.

Sources of information

- Available scientific literature
- Available national and international regulatory documents

- Opinions of lecturers, students, practising X-ray laboratory assistants, employers, and experts (specialists in imaging diagnostics and dental medicine)

Stages of the study

Research was conducted in 5 stages, described in Table 1.

Research instruments

The main part of the study was carried out independently by the doctoral student. All selected partners were briefed in advance on the aim and methodology of the study and trained in using the questionnaires. Each participant completed an anonymous questionnaire, having previously provided consent for participation in the study.

- A hybrid form of surveying was used through the completion of online surveys distributed via social networks of professional organisations, as well as through print-out questionnaires.
- Experts from the fields of Radiology and Dental Medicine were interviewed after previously declaring their consent.

TABLE 1. Stages of the study

STAGE	ACTIVITIES	SCOPE (GROUP – NUMBER)	LOCATION	INSTRUMENTS
Stage I 03.2023 – 12.2023	Problem investigation: Formulation of the topic, object, and subject of the study Defining aims, objectives, and hypotheses ✓ Selection of research methods and instruments		Varna	Literature sources, publications, references, statistical data, and regulatory documents

STAGE	ACTIVITIES	SCOPE (GROUP – NUMBER)	LOCATION	INSTRUMENTS
Stage II 08.2024 – 03.2025	Field work: Conducting an anonymous survey questionnaire ✓ Conducting semi-structured interviews with experts from the fields of Dental Medicine and Radiology	Lecturers – 24 Students – 127 Radiologic technologists – 113 Employers – 46 Experts from Dental Medicine and Radiology specialities – 7	Sofia Plovdiv Varna Pleven Dobrich Shumen Veliki Preslav Omurtag Varna	Questionnaires No. 1, 2, 3, 4 Semi-structured interview questionnaire
Stage III 04.2025 – 08.2025	Data processing and analysis		Varna	• SPSS v. 26.0 • QDA Miner Lite
Stage IV 09.2025 – 11.2025	Description of results		Varna	
Stage V 12.2025 – 01.2026	Conclusions, recommendations, and contributions		Varna	

1.4. Study Methods

The aim of research necessitates the use of a complex of documentary, sociological, and statistical methods.

1.4.1. Documentary method: review of literature, documents, and images describing the investigated issue.

1.4.2. Sociological methods

- Conducting a survey through a specifically developed direct, anonymous, individual questionnaire for each group of respondents, containing questions allowing for comparison:

- Questionnaire No. 1 (lecturers on special subjects in the X-ray Laboratory Assistant speciality)
- Questionnaire No. 2 (students in the X-ray Laboratory Assistant speciality)
- Questionnaire No. 3 (practising X-ray laboratory assistants)
- Questionnaire No. 4 (employers)

- Expert assessment through semi-structured interviews with experts in the fields of Radiology and Dental Medicine in Varna regarding the competencies of X-ray technicians in the use of digital technologies in practice and the need for additional training. The content of the semi-structured interviews was analysed using a thematic approach with the aid of QDA Miner Lite software. It was used for coding, categorisation, and identification of recurring themes and concepts, contributing to a deeper understanding of expert opinions.

1.4.3. Statistical methods

- Variation analysis – measures differences in the mean values of a dependent variable across different groups within a study population;
- Non-parametric tests – χ^2 analysis for evaluating associations between qualitative variables;
- Graphical presentation of the processed data from the study.

Data from the surveys were coded and entered into Microsoft Excel, and the statistical software SPSS for Windows, version 26.0, was used for the purposes of summarisation and statistical analysis.

1.5. Research Instruments

To achieve the aims and objectives of the study, the following were developed:

- **Questionnaire No. 1** for lecturers delivering special subjects, covering the studied characteristics with 24 questions, of which 1 is open-ended, 13 are closed, and 10 are rating scales.

- **Questionnaire No. 2** for students in the speciality, covering the studied characteristics with 24 questions, of which 1 is open-ended, 11 are closed, and 12 are rating scales.
- **Questionnaire No. 3** for practising X-ray laboratory assistants, covering the studied characteristics with 21 questions, of which 13 are closed, and 8 are rating scales.
- **Questionnaire No. 4** for employers, covering the studied characteristics with 21 questions, of which 13 are closed, and 8 are rating scales.

All questionnaires include questions related to the socio-demographic characteristics of the respondents, as well as questions corresponding to the set objectives, allowing for comparison.

- **Semi-structured interview questionnaire** with 13 questions for experts from the fields of Radiology and Dental Medicine.

The interview includes the following questions, without strictly adhering to the order in which they are posed:

1. Opinion on the readiness of X-ray technicians to work with digital imaging diagnostics;
2. Opinion on the theoretical and practical training of X-ray laboratory assistants in the field of dental imaging diagnostics;
3. Opinion on the need to introduce an elective course in the curriculum, aimed at forming additional competencies for X-ray laboratory assistants in working with digital imaging diagnostics;
4. Opinion on the applicability of the proposed elective course program in practice, as well as recommendations for its optimisation;
5. Opinion on the factors contributing most to the mastering of competencies for working with dental digital equipment;
6. Opinion on the topics in the curriculum of the elective course;

7. Opinion on recommendations for improving the educational process and preparing students to work with dental digital equipment.

The respondents were personally invited by the researcher, and interviews were conducted face-to-face at their workplaces in private rooms, free from external distractions. Average duration: approximately 30 minutes.

II. RESULTS AND DISCUSSION FROM THE SURVEY CONDUCTED AMONG LECTURERS, STUDENTS, MEDICAL SPECIALISTS, AND EMPLOYERS

2.1. Socio-demographic Characteristics of the Studied Groups

Socio-demographic characteristics of the lecturers in the X-ray Laboratory Assistant speciality

The study investigated the opinions of 24 lecturers from the four medical colleges in the country where training in the speciality is conducted.

The largest share of lecturers who participated in the survey is from the Medical College – Varna – 41.7% (n=10), followed by the Medical College – Sofia – 29.2% (n=7). The medical colleges in Plovdiv and Pleven are represented by 16.7% (n=4) and 12.5% (n=3) of participants, respectively (Fig. 1).

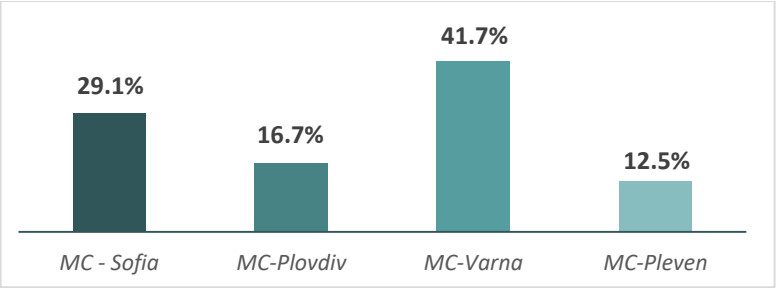

Figure 1. Distribution of lecturers by workplace

Socio-demographic characteristics of the studied X-ray laboratory assistants

113 X-ray laboratory assistants from across the country participated in the survey. Among the participants, women significantly outnumber men – 74.3% (n=84) versus 25.7% (n=29), indicating that the female gender predominates in the profession. The average length of professional experience of the respondents is 9.9 years (± 7.5 years) (Fig. 2).

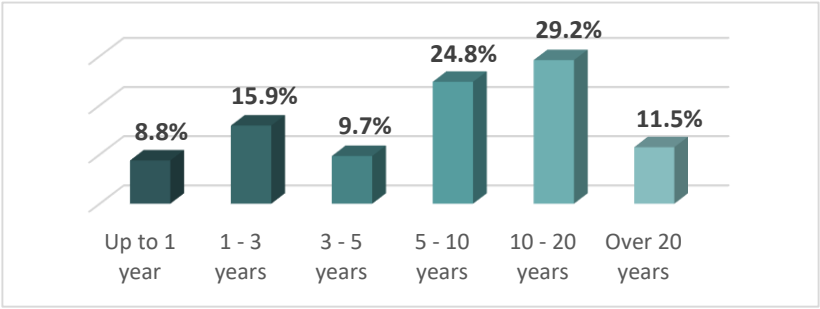

Figure 2. Distribution of X-ray laboratory assistants by years of professional experience

Socio-demographic characteristics of the studied students in the X-ray Laboratory Assistant speciality

127 students in the X-ray Laboratory Assistant speciality were included in the study. The gender distribution shows a significant predominance of women, who are 77.2% (n=98) of all surveyed students. Men are represented in a smaller proportion – 22.8% (n=29). The distribution of respondents by institution demonstrates participation of students from all four medical colleges in the country.

The largest share of respondents is from the Medical College – Varna (38.6%, n=49), followed by the Medical College – Sofia (30.7%, n=39). The medical colleges in Plovdiv and Pleven are represented by 20.5% (n=26) and 10.2% (n=13) of students, respectively (Fig. 3).

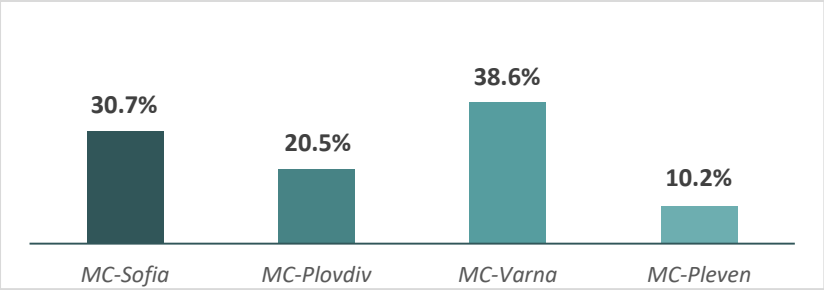

Figure 3. Distribution of students by college

Socio-demographic characteristics of the studied employers

46 employers participated in the study. In 45 of the institutions represented by the surveyed employers, there are medical specialists currently employed who are graduates of the X-ray Laboratory Assistant speciality.

The distribution of employers by gender shows that 60.9% (n=28) are men, while women constitute the remaining 39.1% (n=18) of respondents.

2.2. Current State of X-ray Laboratory Assistant Training

The present analysis is based on the opinions of four key groups in the sector – lecturers, students, X-ray laboratory assistants, and employers.

Assessment of the level of theoretical and practical training of students in the X-ray Laboratory Assistant speciality in the field of dental radiographic diagnostics

Regarding theoretical training, lecturers show satisfaction with the level of knowledge, giving positive ratings of "very high" (20.8%, n=5) and "high" (58.3%, n=14). Only 8.4% (n=2) rated it as "low."

Students assess their level of theoretical training in a more varied manner. Of them, 55.1% rate their training as "very high" or "high," while 44.9% rate it as "medium" or "low." This points to perceived gaps in student training.

X-ray technicians are more critical of their theoretical training, with only 5.3% rating it as "very high" and 39.8% as "high." The highest percentage of X-ray technicians rate their initial level of theoretical competence as "average/medium" – 44.2% (n=50) (Fig. 4).

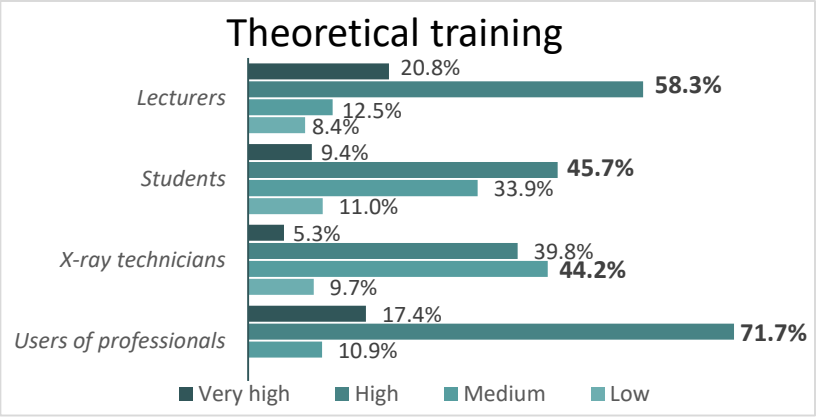

Figure 4. Assessment of the level of theoretical training of X-ray laboratory assistants in dental imaging diagnostics

Employers give the highest rating to theoretical training, with 71.7% (n=33) rating it as "high".

Statistical analysis reveals statistically significant differences between the ratings of X-ray technicians and the other two groups. The discrepancies in opinions are considerable, both between X-ray technicians and employers (χ^2=27.622, p=0.000) and between X-ray technicians and lecturers (χ^2=12.927, p=0.012).

Regarding the practical training of students in the X-ray Laboratory Assistant speciality, lecturers rate it highest: 50.0% (n=12) rate it as "high" and 41.7% (n=10) as "medium".

Students, however, rate their practical training significantly more critically. Only 31.5% of them consider the level of practical skills to be "high" or "very high." The predominant proportion of students (44.1%, n=56) rate it as "average," and 23.6% (n=30) rate it as "low." These findings point to shortcomings in practical training and highlight the need for more hands-on experience in real-world settings (Fig. 5).

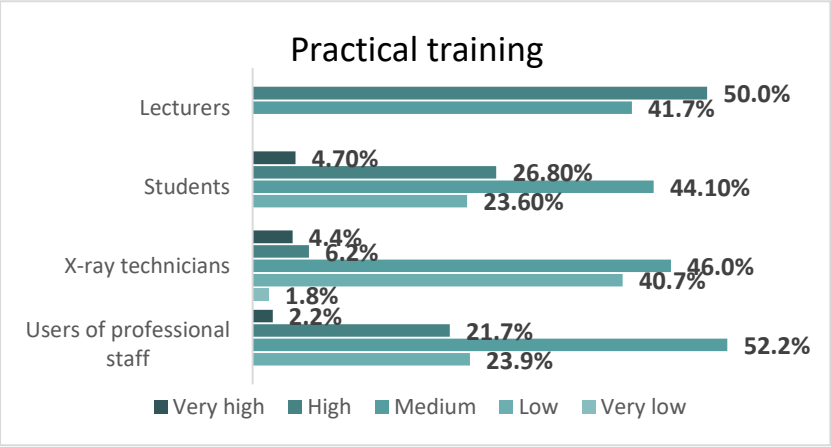

Figure 5. Assessment of the level of practical training of X-ray laboratory assistants in dental imaging diagnostics

X-ray laboratory assistants are also critical of their practical training level. They rate it in the "average-to-low" range, with 46.0% indicating "medium" and 42.5% finding it "low" or "very low." These results underscore the need for more intensive practical training.

Employers' ratings are more evenly distributed. While 23.9% consider practical training "low" and 21.7% "high," the most common rating (52.2%, n=24) is "medium."
Statistical analysis reveals significant differences in assessments of the level of practical training among the four groups:

- Between X-ray laboratory assistants and employers: χ^2 = 11.880, p = 0.036
- Between X-ray laboratory assistants and lecturers: χ^2 = 43.745, p = 0.000
- Between X-ray laboratory assistants and students: χ^2 = 21.979, p = 0.001
- Between lecturers and employers: χ^2 = 14.461, p = 0.006

2.3. Methods and Tools Used in Practical Exercises

The results of the study show that practical training in a real-world environment is the strongest factor for acquiring proficiencies, according to all groups of respondents. This opinion is expressed by 95.8% (n=23) of lecturers, 91.3% (n=116) of students, 64.6% (n=73) of X-ray technicians, and 82.6% (n=38) of employers (Fig. 6).

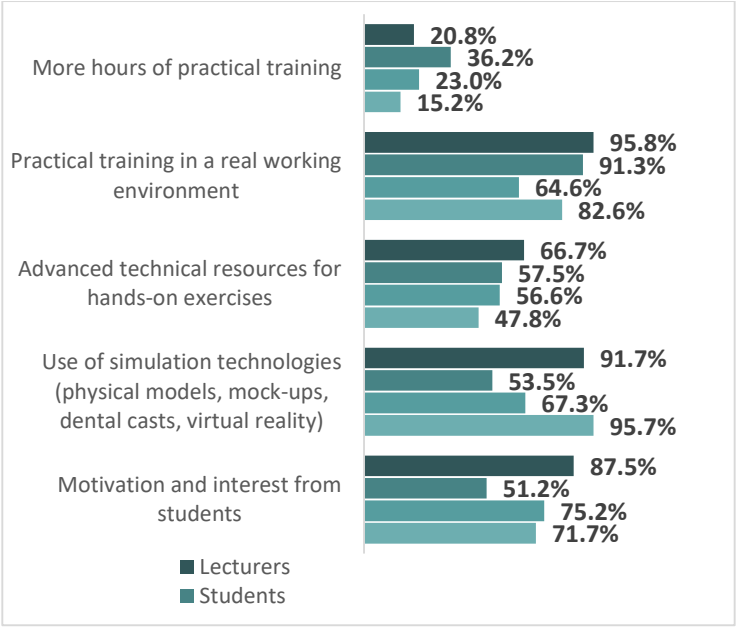

Figure 6. Assessment of conditions and methods facilitating the acquisition of proficiencies for working with dental digital equipment

The results of the chi-square (χ^2) test reveal statistically significant differences in the opinions of the various groups of respondents.

Addressing the need for increased practical hours, students' opinions differ statistically significantly from those of employers and X-ray technicians ($\chi^2 = 7.010$, $p = 0.008$ and $\chi^2 = 4.970$, $p = 0.026$, respectively). This indicates that students perceive the number of practical hours as a greater problem compared to practising specialists, who are most likely to prioritise training quality rather than its duration (Table 2).

TABLE 2. Statistically significant differences regarding the assessment of conditions and methods facilitating the acquisition of competencies for working with dental digital equipment

METHODS AND RESOURCES		П	ПК	РЛ	С
More hours	С		$\chi^2 = 7{,}010$ $p = 0.008$	$\chi^2 = 4{,}970$ $p = 0.026$	
Real working environment	РЛ	$\chi^2 = 9{,}208$ $p = 0.002$	$\chi^2 = 5{,}030$ $p = 0.025$		$\chi^2 = 25{,}544$ $p = 0.000$
Use of simulators	С	$\chi^2 = 12{,}628$ $p = 0.000$	$\chi^2 = 27{,}023$ $p = 0.000$		
	РЛ	$\chi^2 = 5{,}792$ $p = 0.016$	$\chi^2 = 14{,}239$ $p = 0.000$		$\chi^2 = 5{,}221$ $p = 0.022$
Motivation	С	$\chi^2 = 10{,}860$ $p = 0.001$	$\chi^2 = 5{,}811$ $p = 0.016$	$\chi^2 = 14{,}745$ $p = 0.000$	

Legend:
T – Lecturers
E – Employers
RT – X-ray laboratory assistants
S – Students

Training methods and tools used in teaching practice

The survey results among lecturers show that multimedia presentations are the most frequently used teaching methods, with 95.8% (n=23) of lecturers applying them (Fig. 7).

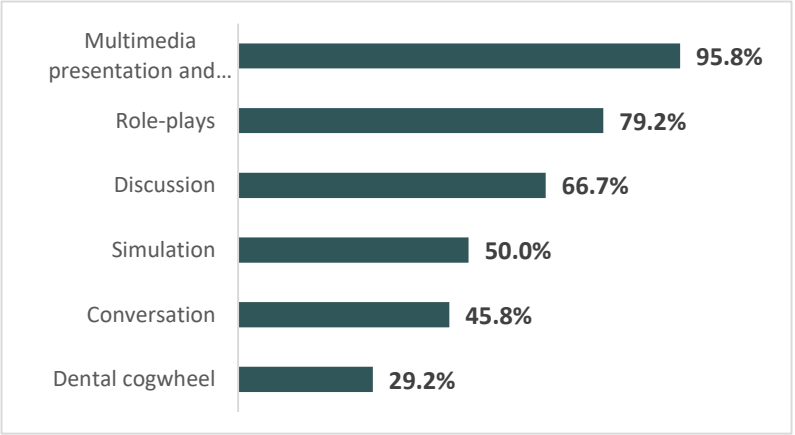

Figure 7. Training methods and tools used in teaching practice

The analysis reveals a statistically significant difference among lecturers from the four colleges training X-ray laboratory assistants, solely with regard to simulation-based training ($\chi^2 = 9.886$, $p = 0.020$). This suggests that the use of simulations varies, likely due to differences in facilities, resources, program guidelines, or teaching approaches.

Use of anthropomorphic phantoms and training benefits

The largest share of lecturers (95.8%, n=23) believe that phantoms contribute to improving the quality of training, underscoring their importance as a tool in preparing students in dental radiography.

Furthermore, three-quarters of lecturers (75.0%, n=18) indicate that working with a phantom facilitates the memorisation of the stages of the radiographic process.

Over two-thirds of lecturers (66.7%, n=16) note that training with a phantom makes the subject matter more accessible to understand, due to the opportunity for students to practice in a controlled environment.

Nevertheless, a comparatively smaller percentage (33.3%, n=8) consider that the use of phantoms saves time to study the theoretical foundations before progressing to clinical practice (Fig. 8).

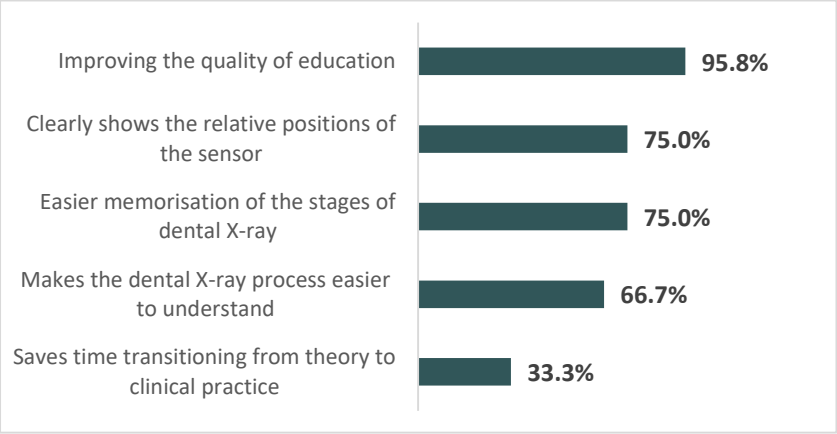

Figure 8. Benefits of using a realistic model or phantom head in practical training

2.4. Competencies of X-ray laboratory assistants for working with dental digital imaging diagnostics

Assessment of the significance of competencies required for dental digital imaging diagnostics

The opinions of three groups of respondents were compared across seven key competencies.

Regarding *knowledge of digital image acquisition*, the largest share of lecturers (66.7%, n=16) and X-ray laboratory assistants (82.3%, n=93) rate this competency as "important." At the same time, the prevailing opinion among students is that it is "moderately important" (42.5%, n=47), indicating different degrees of perceived significance among respondents (Fig. 9).

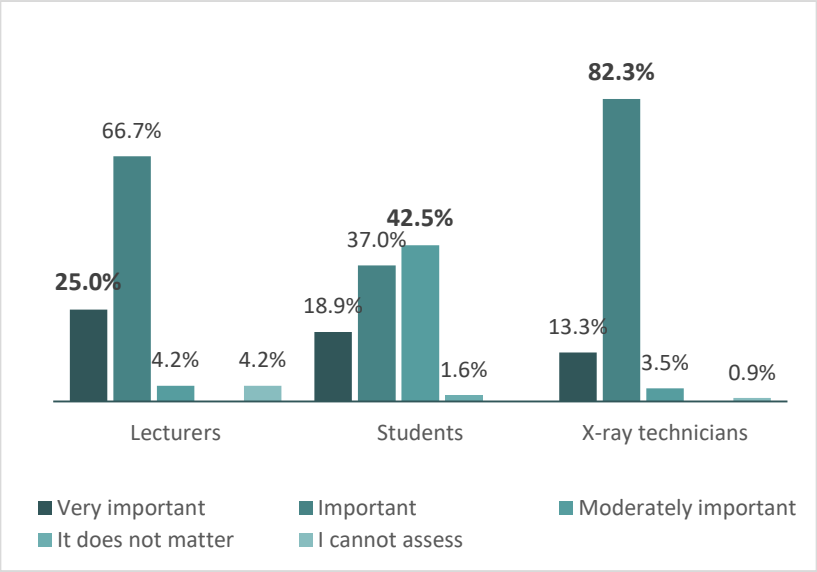

Figure 9. The significance of knowledge of digital image acquisition

The skill of post-processing digital images receives the highest percentage for "very high" significance among two of the surveyed groups (Fig. 10).

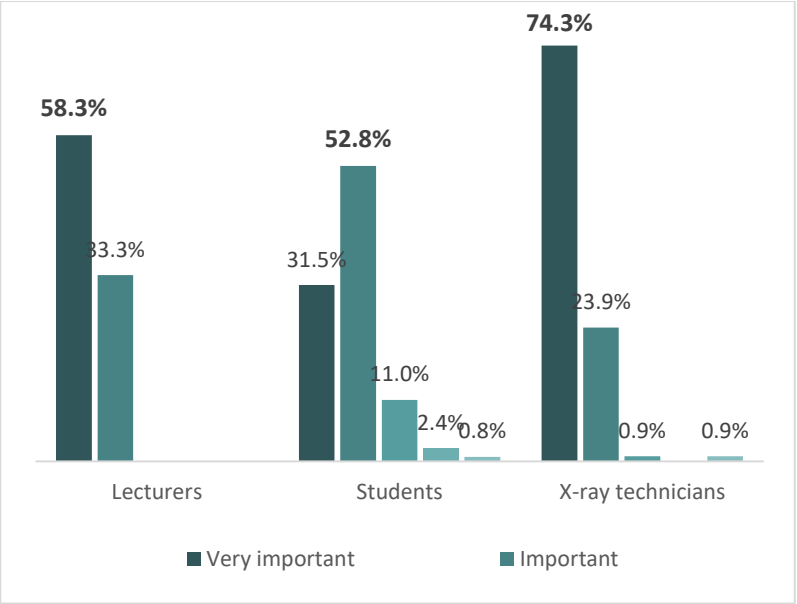

Figure 10. The significance of the skill of post-processing digital images

The highest proportion for this maximum rating is found in the responses of lecturers and X-ray Laboratory assistants, at 58.3% (n=14) and 74.3% (n=84) respectively. At the same time, 52.8% (n=67) of students rate this competency as "important."

The competency related to assessing the diagnostic acceptability of acquired images also finds a very high degree of significance among respondents. Lecturers and X-ray Laboratory assistants most frequently rate it as "very important," at 62.5% (n=16) and 59.3% (n=67) respectively. Among students, the highest proportion of responses is found in the "important" rating – among 54.3% (n=76) of respondents (Fig. 11).

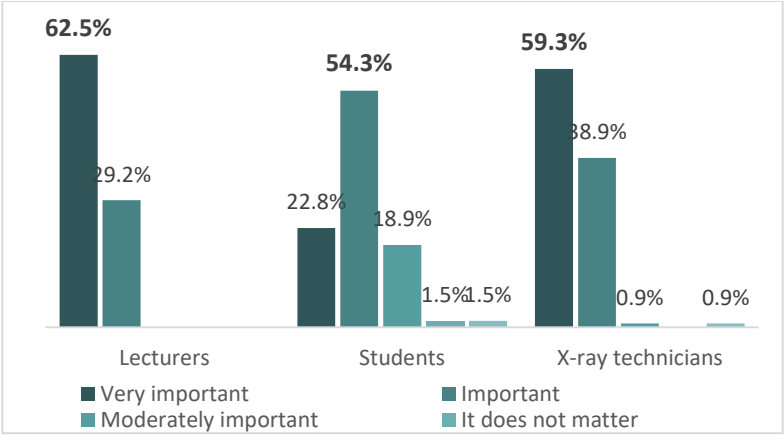

Figure 11. Significance of the skill of assessing the diagnostic acceptability of acquired images

The ability to apply knowledge in practice receives the highest ratings for maximum significance from all three groups of respondents. The opinion is most definitively expressed by lecturers at 91.7% (n=22), followed by X-ray laboratory assistants (91.1%, n=103) and students (68.5%, n=87), who rate this competency as "very important" (Fig. 12).

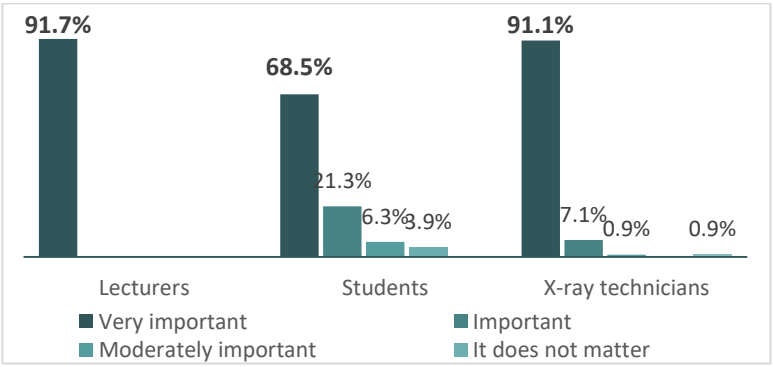

Figure 12. Significance of the ability to apply knowledge in practice

The second competency for which the majority of respondents from all three groups give the maximum significance rating is *independent work skills*. It is rated as "very important" by 83.3% (n=20) of lecturers, 70.9% (n=90) of students, and 86.7% (n=98) of X-ray technicians (Fig. 13).

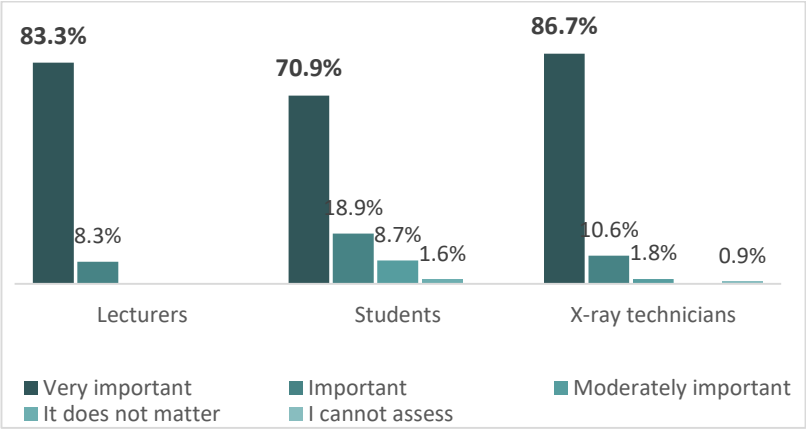

Figure 13. Significance of independent work skills

Unlike the previous two competencies, the ability to manage non-standard situations does not have such a pronounced predominance among respondents regarding a specific significance rating. In the "important" category, it is favoured by two of the surveyed groups – lecturers and X-ray technicians – at 62.5% (n=15) and 69.0% (n=78) respectively. Among students, the weight of the "very important" and "important" ratings is very similar, differing by less than one percent, with a slight advantage for maximum significance (46.9%, n=53 vs. 46.0%, n=52) (Fig. 14).

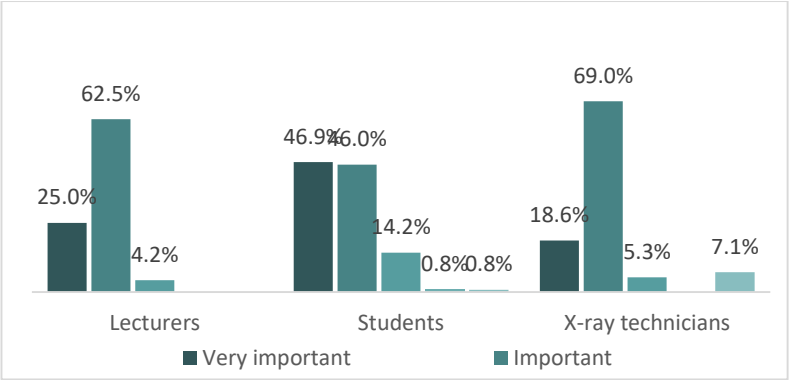

Figure 14. Significance of the skill of managing non-standard situations

The chi-square test of the opinions of lecturers, students, and X-ray technicians regarding the significance of key competencies required for dental digital imaging diagnostics revealed statistically significant differences in ratings. The greatest statistically significant differences are observed between students and X-ray technicians, particularly in knowledge of digital image acquisition ($\chi^2 = 62.691$, $p = 0.000$) and the skill of using information technology ($\chi^2 = 87.001$, $p = 0.000$). Significant differences were also noted between lecturers and students, and between lecturers and X-ray technicians, indicating different professional perspectives and levels of experience in evaluating these proficiencies (Table 3).

TABLE 3. Statistically significant differences assessing the significance of seven competencies required for dental digital imaging diagnostics

Competencies	Statistically significant difference in the opinions of each pair of groups surveyed		
	Lecturers and Students	Lecturers and X-ray technicians	X-ray technicians and students
Knowledge of obtaining digital images	$\chi^2 = 18{,}456$ $p = 0.001$		$\chi^2 = 62{,}691$ $p = 0.000$
Information technology skills	$\chi^2 = 23{,}762$ $p = 0.000$	$\chi^2 = 15{,}724$ $p = 0.003$	$\chi^2 = 87{,}001$ $p = 0.000$
Follow-up processing of digital images	$\chi^2 = 19{,}795$ $p = 0.001$	$\chi^2 = 10{,}008$ $p = 0.040$	$\chi^2 = 25{,}882$ $p = 0.000$
Diagnostic acceptability of the obtained images	$\chi^2 = 29{,}440$ $p = 0.000$	$\chi^2 = 31{,}531$ $p = 0.000$	$\chi^2 = 25{,}982$ $p = 0.000$
Putting knowledge into practice	$\chi^2 = 19{,}643$ $p = 0.001$	$\chi^2 = 12{,}658$ $p = 0.013$	$\chi^2 = 15{,}259$ $p = 0.004$
Independent decision making	$\chi^2 = 14{,}779$ $p = 0.005$	$\chi^2 = 10{,}019$ $p = 0.040$	$\chi^2 = 19{,}459$ $p = 0.001$
Coping with unusual situations	$\chi^2 = 16{,}136$ $p = 0.006$	$\chi^2 = 11{,}704$ $p = 0.020$	$\chi^2 = 28{,}489$ $p = 0.000$

Given the differences in the ratings of the three groups of respondents with respect to all seven competencies, and in order to systematise respondents' opinions, we calculated the arithmetic mean rating on the scale with the highest proportion for each competency (Fig. 15).

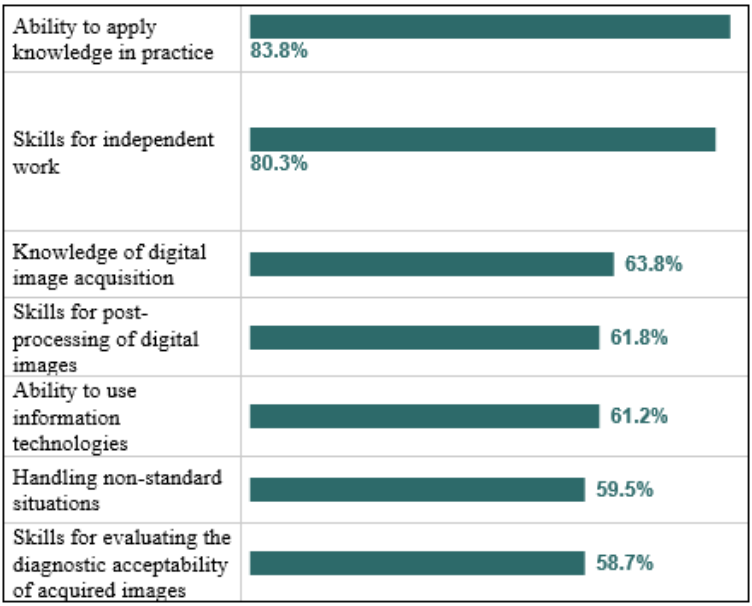

Figure 15. Ranking of competencies by significance according to surveyed groups (arithmetic mean rating from the opinions of lecturers, X-ray technicians, and students)

Analysis of the results shows that the highest significance ratings ("very high") were given to four competencies, two of which do not represent specific technical skills but are broader and more complex – *the ability to apply knowledge in practice and the skill of independent work.*

Ranking of competencies required for dental digital imaging diagnostics by importance

Following the analysis of the competency significance ratings, the next part of the study aims to provide a more detailed picture of the priorities of the different respondent groups (Fig. 16).

Figure 16. Ranking of competencies required for working with dental digital imaging diagnostics by importance

Notably, among the top four competencies, three are technical, while one – adequate communication and obtaining informed consent – is non-technical.

2.5. Assessment of the need for additional training

The study results show a high degree of conviction among respondents that additional training in the field of dental digital diagnostics will contribute to expanding the competencies of students

necessary for their future clinical practice. A definitive positive response was given by 83.2% (n=94) of X-ray laboratory assistants, 82.6% (n=38) of employers, 70.9% (n=90) of students, and 54.2% (n=13) of lecturers. Additionally, approximately one-third of lecturers and one-quarter of students indicated that they would rather share this opinion (Fig. 17).

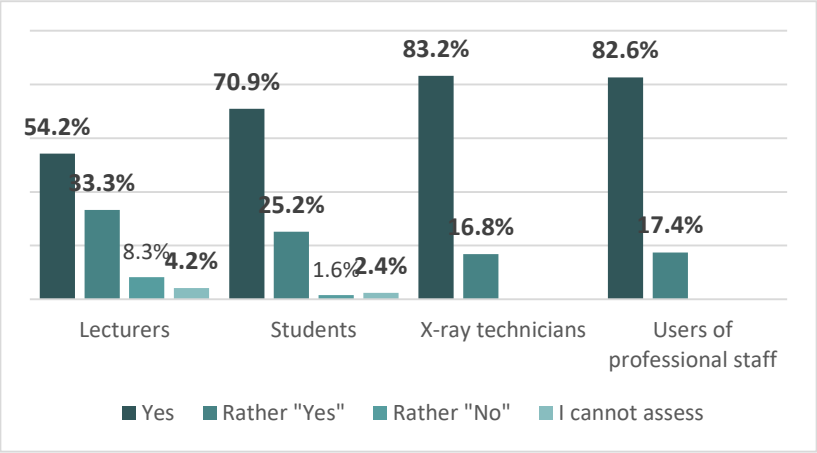

Figure 17. Expected impact of additional training on the competencies of X-ray Laboratory Assistant speciality students

Statistical analysis reveals statistically significant differences between the ratings of lecturers with employers ($\chi^2 = 9.255$, $p = 0.026$) and X-ray technicians ($\chi^2 = 19.000$, $p = 0.000$). These differences may be explained by the different perspectives of academic representatives compared to practising specialists.

Preferred form of additional training

Respondents were asked to indicate which of the two proposed forms of training – an Elective Course (EC) or Postgraduate Training (PGT) – is more appropriate for additional training.

The results show a clearly expressed preference for the EC, with this choice dominating across all groups of respondents (Fig. 18).

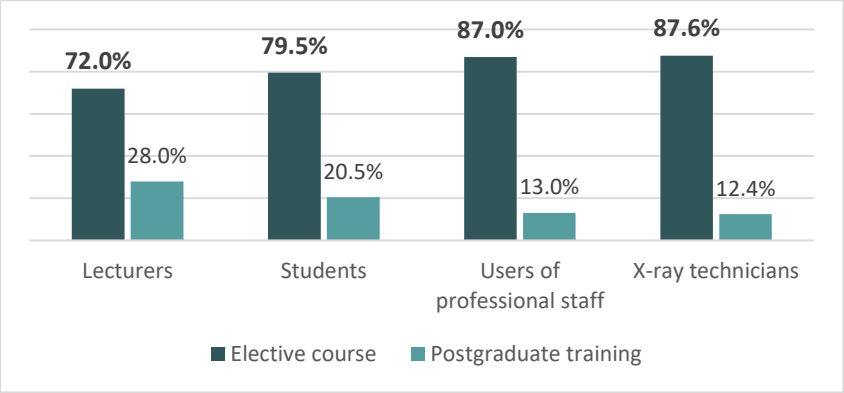

Figure 18. Preferred form of additional training

Priority knowledge and skills to be acquired through additional training

One of the key areas assessed in the study is the need to acquire additional *theoretical knowledge* in the field of dental digital diagnostics.

The highest approval for expanding theoretical training is expressed by employers, among whom 45.7% (n=21) fully support the need for additional knowledge, and 50.0% (n=23) answered "rather yes," indicating near-total consensus among them. Among students, 38.6% (n=49) definitely support the significance of theoretical training, and 51.2% (n=65) answered "rather yes," also demonstrating a strongly positive attitude.

Lecturers and X-ray technicians also acknowledge the need for expanding theoretical knowledge, with "Rather Yes" indicated by 20.8% and 22.1% respectively (Fig. 19).

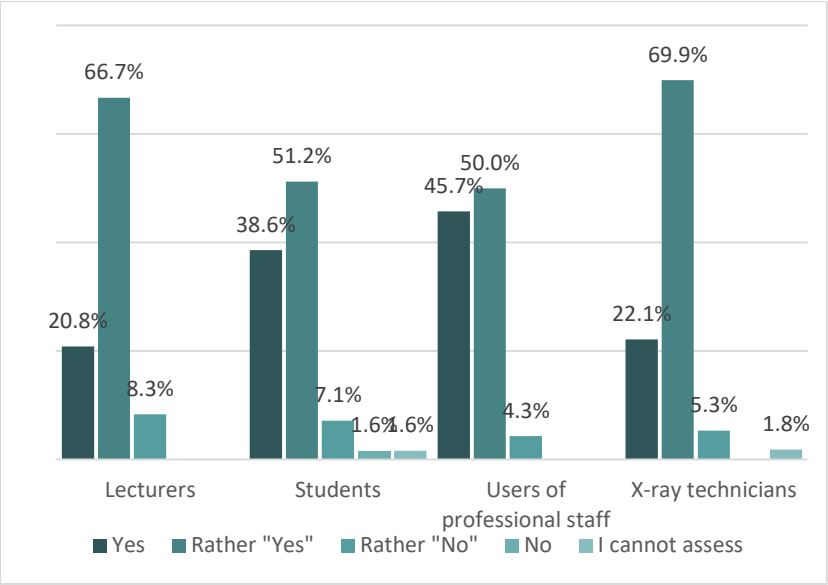

Figure 19. Need for additional training to expand theoretical knowledge

In addition to theoretical training, the study also analysed the significance of developing practical skills in dental digital diagnostics. The results show an even stronger support for this compared to theoretical knowledge.

Nearly 100% of all respondents support additional training focused on developing practical skills, with the most definitive support expressed by 84.8% (n=39) of employers and 83.2% (n=94) of X-ray laboratory assistants (Fig. 20).

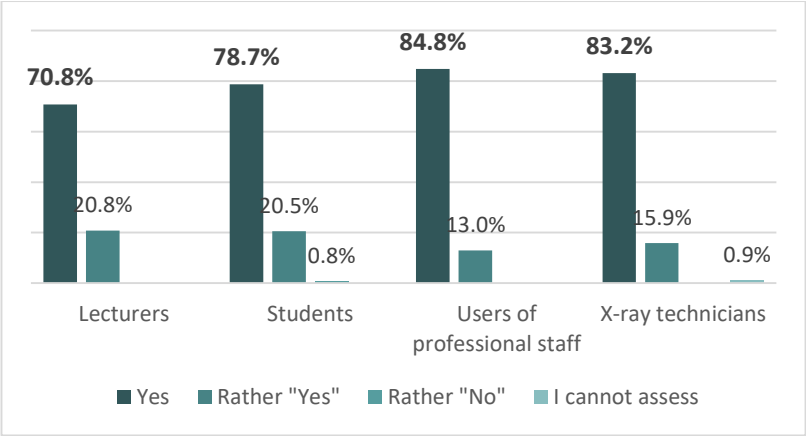

Figure 20. Need for additional training to develop practical skills

Students also demonstrate a high appreciation for the significance of practical training – 78.7% (n=100). A similar result is observed among lecturers, where 70.8% (n=17) fully support training for developing practical skills, and 20.8% (n=5) answered "Rather Yes," again demonstrating high consensus.

In this context, the *processing of dental images* also stands out as a key competency rated by respondents as a priority for additional training. The highest share of definitive positive responses ("yes") is observed among students (70.9%, n=90), followed by X-ray technicians (68.1%, n=77) and employers (60.9%, n=28) (Fig. 21).

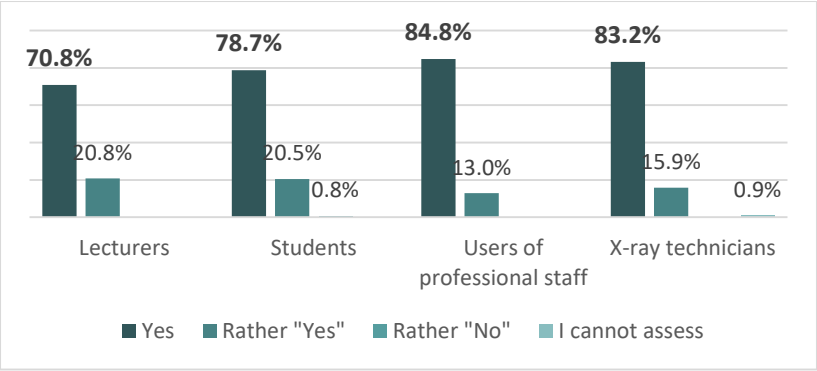

Figure 21. Need for additional training in dental image processing

Among lecturers, "yes" and "rather yes" responses are evenly distributed (45.8%, n=11 each), indicating that the group as an entity maintains a positive attitude toward including this skill in additional training. A high "rather yes" share is also noted among employers (39.1%, n=18) and X-ray laboratory assistants (30.1%, n=34), complementing the positive attitudes in these groups.

Digital information management holds a key position among the priority competencies for additional training. Although the positive attitudes toward this skill are clearly expressed, they are somewhat less prominent compared to the previous skill. While in “processing of dental images” three of the groups clearly indicate "rather yes" as the predominant response, here a larger proportion of "rather yes" responses is seen among lecturers (58.3%, n=14), employers (58.7%, n=27), and X-ray laboratory assistants (51.3%, n=58) (Fig. 22).

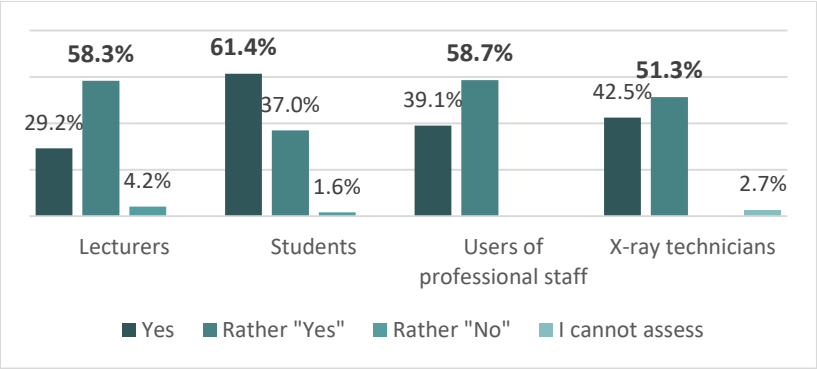

Figure 22. Need for additional training in digital information management

Regarding the skill of independent decision-making, there are less definitive positive responses across all groups, with the highest values observed among students (32.3%, n=41) and lecturers (25.0%, n=6). At the same time, "rather yes" is the predominant response among students (50.4%, n=64) and X-ray laboratory assistants (50.4%, n=57), indicating support for the significance of this skill but also some uncertainty (Fig. 23).

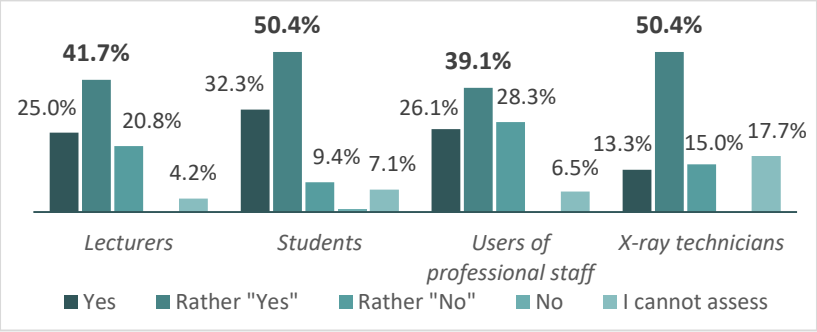

Figure 23. Need for additional training to develop the skill of independent decision-making

Last in the survey is the assessment of the need for *creativity in non-standard situations* (Fig. 24).

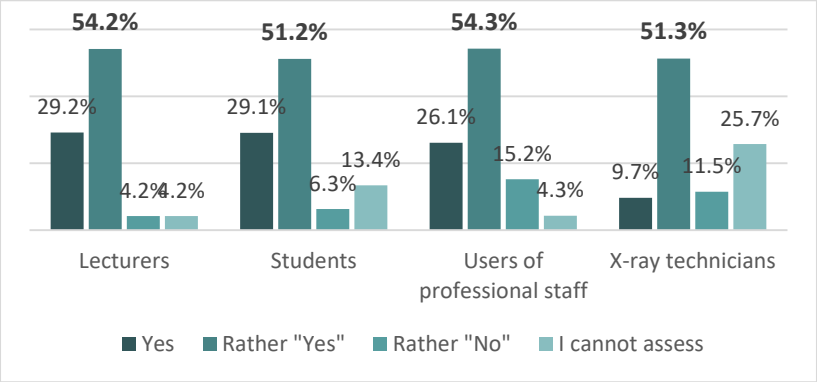

Figure 24. Need for additional training in developing creativity in non-standard situations

The highest share of definitive positive responses ("yes") is observed among lecturers (29.2%, n=7) and students (29.1%, n=37), while among X-ray technicians this proportion is significantly lower (9.7%, n=11). At the same time, "rather yes" is the dominant response in all groups, reaching the highest values among employers (54.3%, n=25) and lecturers (54.2%, n=13), indicating that this skill is perceived as useful, though not of primary importance.

Among X-ray technicians, the highest share of " I cannot assess" responses is observed (25.7%, n=29), which may indicate some uncertainty regarding the applicability of creativity in professional practice. In addition, higher values of "rather no" are recorded among employers and students (15.2%, n=7 and 6.3%, n=8, respectively), which may reflect the understanding that work in radiographic practice is rather standardised and requires adherence to established protocols rather than creative approaches.

Data clearly demonstrate that the most significant future requirement for training is related to the improvement of practical skills (79.4%). This underscores the critical role of practical training in the context of the continuously evolving digital technologies in dental radiology (Fig. 25).

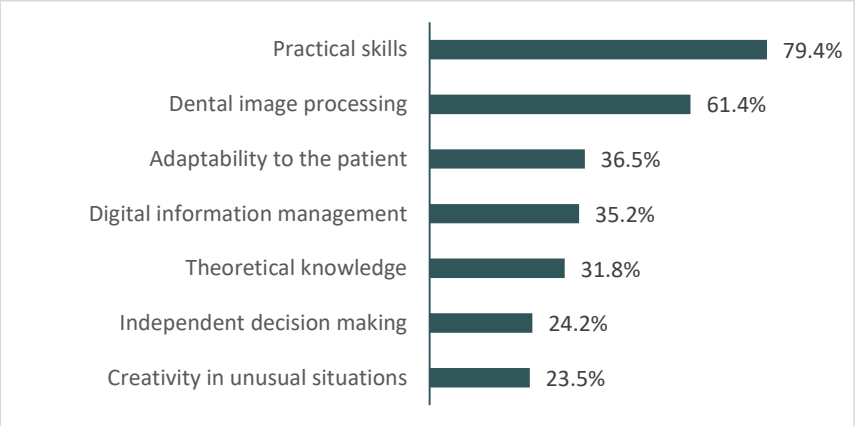

Figure 25. Priority areas for additional training (opinions of lecturers, students, X-ray laboratory assistants, and employers)

Second, at 61.4%, is dental image processing, which is also closely linked to technological advancement. Since these two competencies stand out considerably from the others underscores the need for training focused on mastering new technological proficiencies. Following these, with lower but still significant shares of over one-third of respondents, are the adaptability to different patient categories (36.5%) and digital information management (35.2%).

Less pronounced is the need for additional training in theoretical knowledge (31.8%), independent decision-making (24.2%), and creativity in non-standard situations (23.5%).

This ranking outlines a clear framework for organising the EC content, which should be primarily oriented toward practical skills and working with digital images, in order to meet the dynamic development of technology in dental radiology.

2.6. Areas of Future Development in the Training of Students in the X-ray Laboratory Assistant Speciality

Opportunities for improving the practical training of students in the field of dental radiography

According to respondents, the greatest potential lies in the use of modern simulation technologies, which is strongly supported by both lecturers (87.5%, n=21) and employers (87.0%, n=40). The results underscore the importance of simulation-based training for acquiring skills in a controlled environment (Fig. 26).

Category	Lecturers (%)	Employers (%)
Use of simulation technologies	87.5	87
Providing internship opportunities in dental clinics and centres	70.8	71.7
Improving equipment facilities for practical training	41.7	39.1

Figure 26. Opportunities for improving the practical training of students in the field of dental radiography

Next in line is providing opportunities for internships in dental clinics and centres, supported by 70.8% (n=17) of lecturers and 71.7% (n=33) of employers.

This confirms the importance of real clinical practice for building practical skills and confidence among students.

A smaller but still significant share of respondents emphasise the need to improve the technical infrastructure for training exercises – 41.7% (n=10) of lecturers, and 39.1% (n=18) of employers. This result indicates that, alongside simulations and internships, it is also necessary to modernise the learning environment with equipment and modern software solutions.

Evaluating correlations across the survey results

Analysis of open-ended responses enables us to identify key recurring themes across the various groups of respondents – lecturers, employers, and students. The shared and specific views of respondents regarding training and competencies in the field of dental digital imaging diagnostics are visualised in a diagram.

From the lecturers' perspective, the field necessitates more knowledge in *Clinical Imaging Diagnostics in Dental Medicine/Pathology* and *Imaging Anatomy*, underscoring the importance of these subjects not only for the correct interpretation of radiographic images but also for obtaining high-quality images.

Lecturers and employers share the opinion that Execution of *Radiographic Projections and Positioning* is a critical skill requiring additional attention in the training process (Fig. 27).

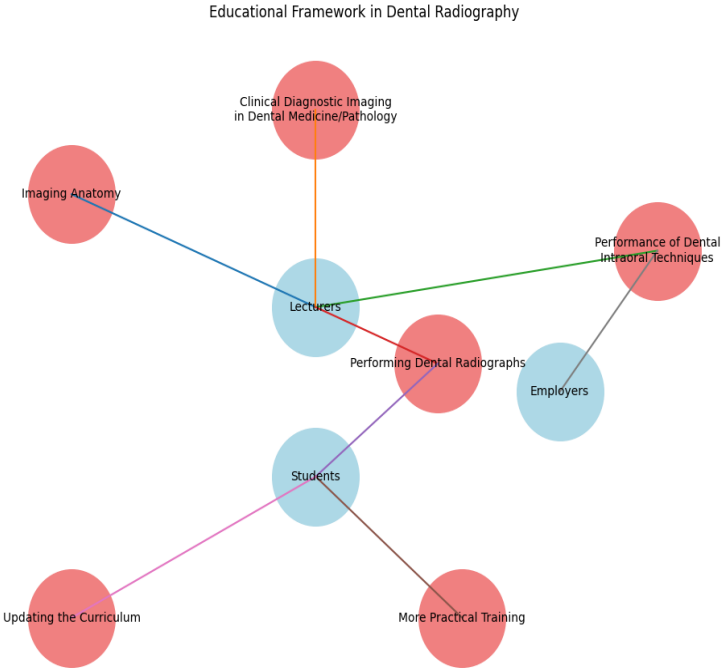

Figure 27. Areas requiring additional training in the field of dental digital diagnostics

The diagram shows that *Conducting X-rays (Radiographs)* is a common area recognised as important by all three groups. This highlights the need for additional training and improvement of proficiencies in this area, which serves as the cornerstone of clinical practice. Students, for their part, place primary focus on practical training. Their responses cluster around the need for *More Practical Training*, including training in a real-world environment, and *Updating Curricula*.

2.7. Expert Assessment

In addition to the opinions of lecturers, employers, X-ray technicians, and students, the survey included a group of seven experts in the fields of imaging diagnostics and dental medicine. Their opinion was obtained through semi-structured interviews.

The results show that all experts are unanimous (100%) that technological advances in dental imaging diagnostics influence the competencies of X-ray laboratory assistants. They are equally unanimous is their opinion regarding the need for additional training for dental digital imaging diagnostics, as well as for introducing an elective course on this topic (Table 4).

TABLE 4. Expert assessment of competencies and the need for additional training of X-ray laboratory assistants

Questions	Yes	No
Do the latest advances in imaging technologies influence the competencies of X-ray laboratory assistants?	100%	
Do you consider X-ray laboratory assistants sufficiently prepared to work with dental digital imaging diagnostics equipment?	57.1%	42.9%
Do X-ray laboratory assistants in your department/clinic possess skills for working with digital equipment?	100%	
Do you believe X-ray laboratory assistants need further training for working with dental digital imaging diagnostic equipment?	100%	
Do you consider that the introduction of an elective course related to dental imaging diagnostics will contribute to the competencies in X-ray laboratory assistants for working with digital imaging equipment, taking into account the global digitalisation in modern healthcare?	100%	

All interviewees are unanimous (100%) that advances in imaging diagnostics are reshaping the duties and responsibilities of X-ray technicians while also demanding further professional development.

Regarding the content of additional training, absolute consensus is observed on the need for topics related to working with different types of digital diagnostic technologies and with image processing software. This highlights the importance of digital competence as a key aspect of preparing future specialists.

Regarding the factors behind the successful mastery of professional skills, all experts are unanimous that practical training in a real environment and the access to advanced resources, equipment and technology are of critical importance. This confirms the need to ensure access to modern equipment and real-conditions from the outset of training. The possibilities for using simulation technologies and educational tools, as well as the qualifications of lecturers and the motivation of students, are also identified as important, but with lower values (Table 5).

The responses of the experts showcase the need for targeted and modernised training, encompassing both theoretical training and access to the latest technological tools in a real clinical environment.

TABLE 5. Experts' perception of the influence of technological advances on X-ray technician competencies and key aspects of additional training

How do technological advances in imaging diagnostics influence the competencies of X-ray technicians (or radiologic technologists)?	
• The roles and responsibilities of X-ray Laboratory assistants have changed	100%
• Require additional training	100%
What topics, in your opinion, should be included in additional training?	
• Information literacy (knowledge and skills for identifying, locating, evaluating, organising,	57.1%

and effectively using and providing information)	
• Working with different types of digital diagnostic technologies	100%
• Working with image processing software	100%
• Working with databases	14.3%
Which factors, in your opinion, contribute most to the mastery of competencies for working with dental digital equipment during the training process?	
• Practical training in a real working environment	100%
• Provision of material and technical resources for practical exercises in accordance with new technologies	100%
• Possibility of using simulation technologies and educational tools (physical models, dental casts, mock-ups, virtual reality)	28.6%
• Qualifications of lecturers	42.9%
• Motivation and interest of students	42.9%

For the purposes of a more in-depth study of expert opinions, in addition to closed questions, the responses to open-ended questions were also gathered and analysed.

The analysis used open-access statistical software for processing textual data – QDA Miner Lite – allowing the systematisation and identification of key issues and trends in the shared opinions.

Analysis of the expert responses to the question: *How do you assess the theoretical training of X-ray laboratory assistants in dental radiographic diagnostics?* enabled us to code four main categories, each examining a different aspect of the assessment.

The results show that all experts assess the theoretical training of X-ray laboratory assistants in dental radiographic diagnostics as

positive. More than half (57.1%) rate it as "good," and the remaining 42.9% rate it as "very good."

Positive attitudes also stand out in the category related to lecturers and the organisation of the training process. Despite the smaller number of responses, experts highlight both the high qualifications of the teaching staff (50%) and the good structure of the training (50%). Regarding the relevance and adequacy of the educational content, opinions vary. Sixty percent of respondents consider it current, but 40% express the need for updating.

The summarised opinion of the interviewed experts regarding the level of theoretical training of X-ray laboratory assistants in the field of dental radiographic diagnostics is presented in Table 6.

TABLE 6. Expert assessment of the theoretical training of X-ray laboratory assistants in dental radiographic diagnostics

Coding and categories	Frequency of responses in category	
	(number)	**(%)**
Overall assessment of theoretical training	**7**	**100%**
• Good	4	57.1%
• Very good	3	42.9%
Relevance and adequacy of educational content	**5**	**100%**
• Current content	3	60.0%
• Need for updating	2	40.0%
Lecturers and organisation of training	**2**	**100%**
• Qualified lecturers	1	50.0%

Coding and categories	Frequency of responses in category (number)	(%)
• Good organisation of training	1	50.0%
Uncertainty in assessment	1	100%
• Lack of sufficient information about the curriculum	1	100%

In addition, we took into account experts' convictions regarding the practical training of students. Analysis of the question: *How do you assess the practical training of X-ray laboratory assistants in dental radiographic diagnostics?* revealed two main aspects: overall assessment of training and specific areas for improvement.

Regarding the overall assessment, 71.4% of experts rate it as "good," indicating a positive attitude toward practical training. Nevertheless, 28.6% indicate the need for improvement, drawing attention to potential challenges in the training process (Table 7).

TABLE 7. Expert assessment of the practical training of X-ray laboratory assistants in dental radiographic diagnostics

Coding and categories	Frequency of responses in category (number)	(%)
Overall assessment of practical training	**7**	**100%**
• Good	5	71.4%
• Need for improvement	2	28.6%
Necessary improvements	**6**	**100%**

Coding and categories	Frequency of responses in category (number)	(%)
• More clinical practice	2	33.3%
• More emphasis on specific professional skills	2	33.3%
• Integration of new technologies into training	4	66.7%
• Training in a simulated environment / with phantoms	1	16.7%

In terms of necessary improvements, expert opinion reveals several key areas. The most frequently mentioned recommendation is the integration of new technologies into training (66.7%), underscoring the importance of modern digital radiographic diagnostic systems.

Moreover, experts emphasise the need for more clinical practice (33.3%) and increased attention to specific professional skills (33.3%). In addition, though less frequently, the need for training in a simulated environment or using phantoms (16.7%) is noted, which could improve the acquisition of practical skills in a controlled educational setting.

Expert opinion on the question: *What form of additional training would you propose?* outlines a clear preference for the elective course (EC). All experts (100%) indicate EC as the most appropriate form of additional training, while one interviewee also mentions PGT as an additional alternative. Arguments favouring the EC relate to the possibility of mastering the latest technologies and methods (40.0%) and creating specific skills in digital radiology (20.0%).

Experts also emphasise that such training would provide an advantage when working in modern dental clinics (20.0%) and would be particularly beneficial for students who intend to specialise in this

area (40.0%). The results clearly indicate the need for structured additional training to equip future X-ray technicians with practical skills tailored to a rapidly evolving field of dental radiology (Table 8).

TABLE 8. Expert opinion on the appropriate form of organising and conducting additional training

Coding and categories	Frequency of responses in category	
	(number)	(%)
Type of additional training	**7**	**100%**
• Elective course (EC)	7	100%
• Postgraduate training (PGT)	1	14.3%
Reasons for choosing the EC	**5**	**100%**
• Will provide an advantage when working in modern dental clinics	1	20.0%
• Training in the latest technologies and methods	2	40.0%
• Mastering specific skills in digital radiology	1	20.0%
• It will be useful for students directing themselves toward this field	2	40.0%

More specific advice was given in response to the question: *Do you have recommendations for improving the educational process and preparing students to work with dental digital imaging diagnostics equipment?* Analysis of the results outlines several main areas for optimising training.

The primary recommendation is the expansion of practical training, with 66.7% of experts emphasising the need for more internships and practical training sessions in dental clinics. Another 33.3% consider that the number of practical hours in dental diagnostics should be increased, and 16.7% recommend earlier introduction of dental diagnostics, from the first year of study.

The second key aspect relates to methods for improving training. According to 66.7% of experts, the use of simulated environments, including phantoms and physical models, would improve the acquisition of practical skills.

The third aspect relates to ensuring access to modern equipment. All experts in this category (100%) recommend organising visits to dental clinics, as well as developing partnerships with dental centers as an effective means of accessing modern equipment.

Additional recommendations include independent training tasks (33.3%) and more clearly defined mentor responsibilities within the training process (33.3%) (Table 9).

TABLE 9. Expert recommendations for improving the educational process and preparing students to work with dental digital imaging diagnostics equipment

Coding and categories	Frequency of responses in category (number)	(%)
Expansion of practical training	**6**	**100%**
• More practical hours in the field of dental diagnostics	2	33.3%
• Ensuring internships and practical training in dental clinics	4	66.7%
• Early introduction to dental diagnostics (from the first year of study)	1	16.7%
Methods for improving training	**3**	**100%**
• Training in a simulated environment (using phantoms and physical models)	2	66.7%
• Self-paced preparatory exercises	1	33.3%
• Discussion of the role of mentors in training	1	33.3%
Ensuring access to modern equipment	**2**	**100%**
• Visits to dental clinics to become familiar with the latest digital radiographic system	2	100%
• Partnerships with dental centres for access to modern equipment	1	50.0%

The expert recommendations converge around a greater practical orientation of training, modernisation of teaching methods, and expanding access to new technologies, in order to ensure the adequate training of future X-ray technicians in dental imaging diagnostics.
In response to the last question: *What topics should be included in the additional training?* some experts offer targeted recommendations for improvement. While not all interviewees give their opinion, the shared recommendations outline three key areas (Table 10).

TABLE 10. Expert recommendations for topics to be included in the EC in dental imaging diagnostics

Category and coding	Frequency of responses in category (number)	(%)
Hands-on approach	**2**	**100%**
• Topics with a practical approach	2	100%
Specific technical aspects	**2**	**100%**
• Artefacts and errors in dental radiographic examinations – causes and methods of correction	1	50.0%
• Radiation protection in dental practice	1	50.0%
• Exposure parameters and analysis of X-ray tube settings	1	50.0%
Communication with patients	**1**	**100%**
• Communication training – explaining the procedure, instructions for stillness	1	100%

Conclusions from the results of the semi-structured interview with experts

The primary recommendation is introducing an EC as a form of additional training. The aim is to provide conditions for more specialised training during the course of study for students who intend

to pursue a career in this field immediately after completing their education.

According to the experts, the EC program should have a clearly expressed practical orientation, providing opportunities for active application of knowledge with the assistance of:

- Modern digital radiographic systems;
- Training in a simulated environment with phantoms and physical models;
- Independent practical tasks for improving skills.

In addition, experts emphasise the need for including subject-specific technical topics such as:

- Recognition and correction of artefacts in radiographic images;
- Optimisation of exposure parameters and X-ray equipment settings;
- Radiation protection in dental practice.

Beyond technical training, experts place emphasis on the development of communication skills, such as giving clear instructions to patients and building trust during the examination process.

III. PRACTICAL APPROACHES

3.1. Development and introduction into the X-ray Laboratory Assistant speciality curriculum, an EC in *Dental Digital Imaging Diagnostics*

The development of the present elective course (EC) program is determined by the results of the conducted study on the competencies of X-ray technicians for working with dental digital imaging diagnostics equipment. Analysis of the collected quantitative and qualitative data outlined certain challenges regarding the training of X-ray Laboratory Assistant speciality students to work with dental digital imaging diagnostics equipment. Significant differences were

noted in competency assessments; the predominant use of traditional teaching methods limits the options for practical application of modern technologies. At the same time, a clearly positive attitude toward additional training in this area was identified. The need for including targeted and structured training as part of the academic program in the form of an EC was highlighted. Based on these findings, a curriculum was developed aimed at a comprehensive and balanced approach to training in dental digital imaging diagnostics.

The aim of the course is for students to acquire in-depth knowledge and practical skills in applying modern digital technologies in dental imaging diagnostics, in line with current requirements of clinical practice and trends in professional training. The premise of the EC content is that the training of X-ray technicians must encompass not only the technical aspects of the radiographic process, but also basic knowledge of anatomical structures, principles of radiation protection, digital image processing and administration, and the use of modern standards for documentation and exchange of information. In addition to these elements, the training emphasises the integration of simulation technologies and working with training phantoms – an approach that allows for the acquisition of key skills in a controlled and safe environment.

In terms of content, the program features 5 lectures paired with 10 practical sessions. The lecture module includes an overview of the history and development of dental imaging diagnostics, the main types of digital technologies and methods, the characteristics of digital images, their software processing, radiation protection standards, and the ethical and communication aspects of working with sensitive digital information. A major focus is placed on cone beam computed tomography (CBCT) in dental practice – a technique that fundamentally transforms visualisation and places new demands on the training of technical staff.

The practical exercises are tailored to key tasks performed by X-ray technicians in a real dental environment. Topics include working with a digital imaging system, performing intraoral projections (bitewing and periapical), assessing image quality, recognising artefacts, fundamentals of three-dimensional visualisation (CBCT), processing and archiving in various file formats (including DICOM), as well as documentation and electronic exchange of images in accordance with confidentiality requirements.
Significant focus is placed on radiological protection, which is often underestimated in dentistry but is of critical importance given the frequent exposure of patients.

Based on the content and the embedded teaching methods, it is expected that students who successfully complete the course will demonstrate the ability to work with the main types of dental digital equipment. They should develop confidence in applying the principles of radiation protection, as well as skills for effective communication with patients and the team, particularly when handling sensitive information and visual material. Not least, the course aims to foster attitudes of continuous professional development and adaptation to new technologies, as well as the ability to work in a digitally-advanced, complex medical environment requiring critical thinking and technological literacy.

The proposed EC not only expands the spectrum of knowledge and skills of future X-ray laboratory assistants in the field of dental diagnostics but also offers the opportunity to integrate modern technologies and approaches into their professional training.

3.2. Development of an Electronic Library of Dental Images as a Training Resource

As part of the applied outcomes accompanying the development and introduction of the elective course, a specialised electronic library of anonymised dental images was created.

The purpose of this resource is to support training by providing access to real clinical images illustrating the diversity of anatomical structures, imaging modalities, and specific oral pathologies.

The primary focus is on distinguishing normal from pathological findings, forming visual thinking, developing the ability to navigate the diversity of dental images, and mastering basic skills in digital processing and technical optimisation of images.

The library is organised in two main directories according to file format – DICOM and TIFF/JPEG – each containing subdirectories structured by modality: intraoral (periapical, bitewing, occlusal), panoramic, and CBCT (Fig. 28). Anonymised images of both adults and children are included, taking into account the specific characteristics of paediatric dental imaging diagnostics – including stages of dental development, resorption of deciduous teeth, and characteristic paediatric conditions.

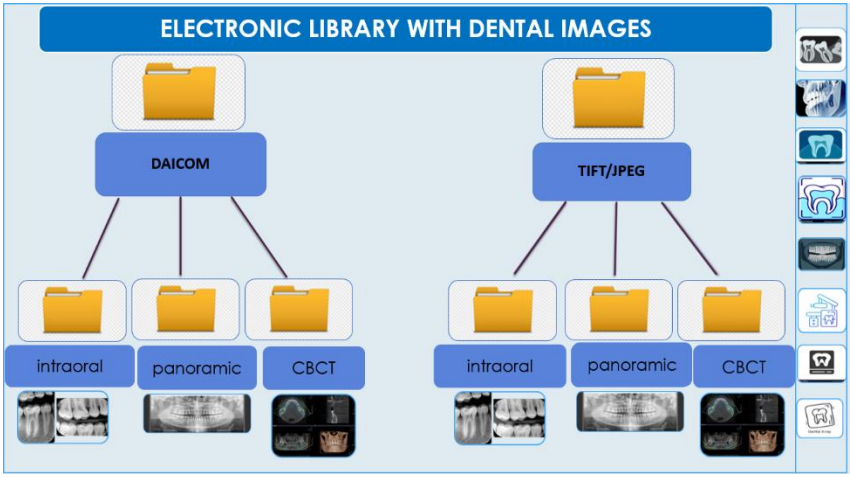

Figure 28. Screenshot of the created electronic library

The electronic library is used exclusively for practical sessions, in a controlled environment. DICOM format images serve to familiarise students with the structure of the medical file, metadata, and the use of specialised visualisation software. TIFF and JPEG format files allow for basic processing exercises – including contrast adjustment, marking, measurement, and export. The library represents a valuable training tool that complements traditional forms of teaching and promotes visual literacy – a key competency in the training of X-ray laboratory assistants.

3.3. Participation in Project No. 23005: *A study on the accuracy of the TMJ movements replicated by a new dental articulator prototype, including central occlusion models, via 3D scanning with a laboratory scanner, CBCT, and conventional methods*

The thesis focus and objective correspond to **three** of the planned and implemented project activities (Fig. 29):

1. Obtaining an image of the object through CBCT scanning; reconstruction of the obtained (2D) data into a three-dimensional (3D) image **(Activity 5).**
2. Optimising the image by adjusting brightness levels, establishing a contrast range, and applying specific filters **(Activity 6)**.
3. Measuring distances between landmarks used in skull analysis – measurements on volumetric data; overlaying of reference points **(Activity 7)**.

The software program for dental design – Exocad – was used for transferring information from the CBCT.

Within the framework of this project, we carried out much of our research and development activities. In addition, the project provided opportunities for expanding the practical training of students in the X-ray Laboratory Assistant speciality in working with the specialised **Planmeca software**, which will undoubtedly enhance their future professional competencies.

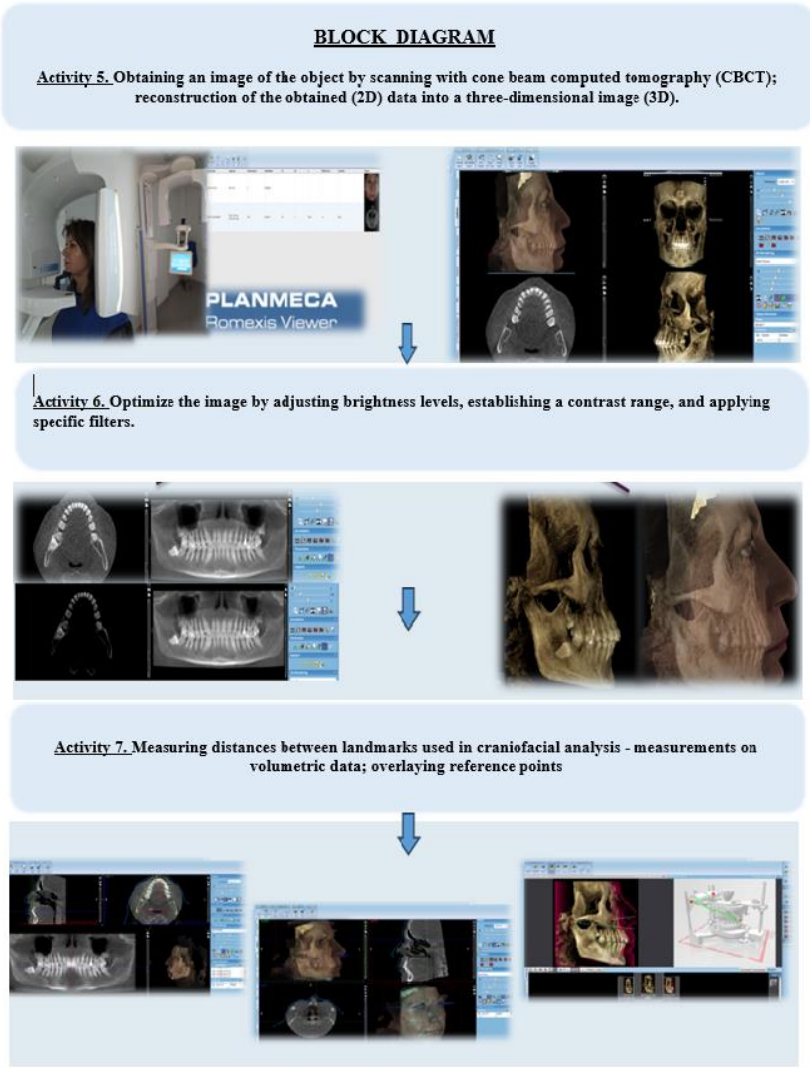

Figure 29. Block diagram of the planned and implemented project activitie

IV. CONCLUSIONS, RECOMMENDATIONS AND CONTRIBUTIONS

CONCLUSIONS

1. There is a discrepancy in the opinions of stakeholders regarding the comprehensive nature of X-ray laboratory assistants' professional training in dental imaging diagnostics.
2. The competencies of X-ray laboratory assistants for working with dental digital radiographic equipment receive contradictory assessments, reflecting differences in training and the practical application of knowledge.
3. Practical training in a real clinical environment contributes most strongly to the effective development of skills in working with dental digital equipment. This reinforces the need for strengthened partnerships between academic institutions and clinical facilities.
4. The predominant use of traditional teaching methods, at the expense of simulation tools, limits the development of key professional skills. This is a prerequisite for more targeted and structured integration of modern simulation technologies into the educational process.
5. Technical skills are assessed as critical to the professional training of X-ray laboratory assistants. Simultaneously, soft skills (cognitive and communicative) are becoming increasingly essential in improving the quality of clinical practice and effective interaction with patients.
6. A clear and widely supported need for additional training in dental digital imaging diagnostics is expressed, with a preference for an elective course (EC) in the main academic program. The differences in attitudes between academic staff and practitioners require more active dialogue to optimise educational content and methods.

7. The elective course (EC) should include a balanced module of theoretical knowledge and practical skills, aimed at the comprehensive training of X-ray Laboratory Assistant speciality students to work with the rapidly evolving digital technologies in dental practice.
8. Key training development priorities have been established. Digitalisation of educational content, interdisciplinary modules, and a closer connection with clinical practice stand out.
9. Experts clearly stress the requirement for targeted additional training of X-ray laboratory assistants for working with dental digital imaging diagnostics equipment.
10. Expert opinion expresses the need for more intensive practical training in a real clinical environment. The provision of advanced infrastructure and technical equipment is thought of as a foundation for future-ready professional skills.

RECOMMENDATIONS

I. To the academic community

1. Introduction of an elective course (EC) in dental digital imaging diagnostics, reflecting contemporary technological advances and developing digital competencies suited to the needs of modern dental practice.
2. Reorganisation of part of the clinical practice through strengthened cooperation with dental clinics and healthcare facilities. This will ensure access to modern equipment and a real-work environment for effective acquisition of professional skills.
3. Integration of simulation techniques and technologies complementary to traditional methods of practical training, to improve the quality and safety of training.

II. To the professional associations (Bulgarian Association of Health Care Professionals; Bulgarian Association of Radiographers in Image Diagnostics and Therapy):

1. Organisation of training sessions, seminars, and practical courses for X-ray laboratory assistants in the field of digital imaging diagnostics.
2. Promotion of joint initiatives between employers and academic institutions to optimise professional collaboration.

III. To the Ministry of Health:

1. Creation of targeted investment programs in infrastructure, facilities and equipment intended for the training of X-ray laboratory assistants in a modern clinical environment for dental imaging diagnostics.

CONTRIBUTIONS

I. Theoretical contributions

1. A comprehensive and systematic study was conducted on the competencies of X-ray Laboratory assistants in dental digital imaging diagnostics, contributing to an objective assessment of educational and professional needs in this field.
2. The main challenges in the training of X-ray Laboratory assistants regarding dental imaging technologies were identified, along with stakeholder expectations concerning the competencies necessary for functioning effectively in a modern practice.
3. The significance of simulation techniques as an effective addition to the practical training for X-ray laboratory assistants under conditions of digitalisation was established.

II. Practical contributions

1. A curriculum for an elective course on *Dental Digital Imaging Diagnostics*, aimed at building digital competencies adequate to the needs of dental practices was developed.
2. A specialised electronic library of real, anonymised dental images was created, structured in directories by file format (DICOM, TIFF/JPEG) and by type of modality (intraoral, panoramic, and CBCT), supporting the development of digital competencies in students by providing opportunities for processing, comparison, and analysis of images.
3. Within the framework of Project No. 23005: *A study on the accuracy of the TMJ movements replicated by a new dental articulator prototype, including central occlusion models, via 3D scanning with a laboratory scanner, CBCT, and conventional methods*, we identified opportunities to expand students' practical training in the X-ray Laboratory Assistant speciality. Their potential is focused on working with the specialised Planmeca software, which will be incorporated into the EC curriculum for the purposes of acquiring practical skills in the analysis and processing of 3D imaging data.

THESIS-RELATED PUBLICATIONS AND PARTICIPATION

1. Kostova E, Angelova S. Imaging methods and techniques in dental practice. *Varna Medical Forum.* 2023;12(2):174–179.
2. Kostova E. Recognition and avoidance of common errors in dental radiography. *Varna Medical Forum.* 2024;13(2):128–131.
3. Project No. 23005: A study on the accuracy of the TMJ movements replicated by a new dental articulator prototype, including central occlusion models, via 3D scanning with a laboratory scanner, CBCT, and conventional methods.