Teka Komisji Architektury, Urbanistyki i Studiów Krajobrazowych
Oddział Polskiej Akademii Nauk w Lublinie / Politechnika Lubelska

Architectural solutions for contemporary dental clinics based on scientific research – a case study

CASE STUDY: https://doi.org/10.35784/teka.8818
Received 01.12.2025, accepted 30.12.2025, published 30.12.2025

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Abstract: **Contemporary dental clinics are complex medical facilities in which functional efficiency, epidemiological safety and user comfort must be equally integrated into the design process. In recent years, especially after the COVID-19 pandemic, the importance of architectural solutions supporting aerosol control and optimised ventilation of treatment rooms has increased. The aim of this study is to analyse current trends and scientific research results concerning the design of the dental environment in the context of evidence-based design (EBD) principles and to present a conceptual model of a dental centre in Lublin, based on an integrated architectural and technical approach. The methodology includes a literature review, identification of key design aspects, and development of a model concept for a dental centre based on scientific research and in-depth interviews with medical staff at one of the dental clinics in Lublin. The results of the analysis indicate that the design of dental clinics requires an integrated approach, combining hygienic and epidemiological principles with psychological and ergonomic factors. The following are of key importance: proper ventilation and air purification systems, central sterilisation areas, a modular layout of treatment rooms, and the use of healing environment strategies, biophilic design, and acoustic solutions to improve user comfort.**

Keywords: dental clinic design, dental centre, evidence-based design (EBD)

1. Introduction

Dental clinics are a key element of medical infrastructure in cities, providing a wide range of services related to oral diagnosis, treatment and prevention. In an era of growing patient expectations and increased hygiene awareness, the architecture of these facilities is no longer just a technical shell – it is a factor influencing clinical safety, user comfort and operational efficiency. In addition, the COVID-19 pandemic has highlighted the importance of designing spaces that take into account aerosol infection control mechanisms and ventilation.

Contemporary dental clinics are complex medical facilities where architecture plays a key role in shaping the quality of treatment, patient comfort and staff efficiency. The design of such spaces requires the integration of functional, ergonomic, technological and aesthetic requirements, while taking into account psychological aspects and user experience. As Lawson notes, the architecture of medical facilities should not only meet technical and sanitary standards, but also support the therapeutic process by appropriately shaping the environment in the medical facility [1].

Technological developments, the digitisation of diagnostic processes and growing patient expectations regarding the quality of medical spaces mean that modern dental clinics are evolving towards interdisciplinary structures that combine therapeutic, educational and research functions [2, 3]. Architecture is becoming a tool for communication between patients and the healthcare system, creating an atmosphere of trust, privacy and safety.

Contemporary designs are characterised by a desire to humanise medical spaces through the use of natural light, natural materials, indoor greenery and biophilic solutions [4, 5]. The flexibility of space is also becoming an important aspect, enabling adaptation to changing technologies and organisational models of healthcare.

The aim of this article is to: (1) analyse the current state of knowledge in the field of dental clinic architecture; (2) identify key design factors; (3) present an original conceptual design for a dental centre in Lublin, developed on the basis of scientific research.

2. State of research

The first group of contemporary studies related to dental clinics addresses issues in the field of ventilation, air distribution and CFD (Computational Fluid Dynamics) simulation. Nambu et al. conducted CFD simulations in a dental clinic model and showed that the presence of a partition between chairs leads to local areas of "air age", indicating poorer air exchange in these areas [6]. Karami et al. simulated the distribution of virus-containing droplets at different ventilation speeds and supply and exhaust locations, indicating that a speed of 5 m/s ensures faster removal of aerosols and reduces the risk of infection [7]. Yang et al. in a study of open dental clinic layouts show that the placement of portable air cleaners has a significant impact on reducing the risk of transmission — even at moderate CADR (clean air delivery rate) [8]. Du et al. demonstrate in 3D models that different ventilation strategies (including mixed ventilation) affect aerosol trajectories and the effectiveness of their elimination [9]. Zu et al. propose an attachment ventilation (AV) model as a way to minimise the spread of aerosols in areas close to walls [10].

The second group of studies covers the characteristics of a healing environment and issues related to patient comfort and perception. Sarapultseva et al. analysed the environment of private and public dental facilities, identifying the characteristics of spaces that influence the perception of cleanliness, comfort and safety [11]. Emami et al. used a discrete choice method for waiting room elements (e.g., lighting, plants, window size), showing that these elements have a statistical impact on patient preferences in terms of perceived stress [12]. Antoniadou et al. developed a review in which they emphasise that the acoustic environment (machine noise, reverberation) is often overlooked, yet has a significant impact on patient feelings and staff fatigue — they propose sound masking strategies, acoustic zoning and the integration of sound-absorbing materials [13]. A systematic review by Al Khatib et al. shows that biophilic designs (green elements, natural forms, access to nature) in medical facilities have a beneficial effect on stress reduction, patient comfort and staff well-being [14].

A review of the literature revealed a limited number of publications directly addressing the issue of dental clinic design, particularly from an architectural perspective. This article provides a general overview of dental clinic design, resulting in a model conceptual proposal for a multifunctional dental centre.

3. Methodology

The research process was carried out in three main stages. In the first stage, a review of the literature on the architecture of medical facilities was conducted, with particular emphasis on dental clinics. The analysis included scientific publications obtained from Google Scholar, Scopus and Web of Science databases. The collected material allowed for the identification of current trends and key aspects of dental space design in functional, ergonomic, technological and psychosocial contexts.

In the second stage, an in-depth analysis of sources relating to the shaping of the architectural environment in medical facilities was carried out. On this basis, a set of design factors with a significant impact on the quality of space in dental centres was identified, including, among others, the organisation of functions, communication layout, material solutions, access to daylight, biophilic elements and visual aspects, etc.

In the third stage, a case study method was used to develop an original conceptual design for a dental centre located in Lublin, which served as a practical verification and development of the identified theoretical assumptions. This design was developed as a proposal to enrich the functional offer of the city centre with a modern, comprehensive

medical centre specialising in dentistry. The study is of a model nature and also includes experimental functional and spatial solutions, developed on the basis of the results of five in-depth interviews with the staff of one of Lublin's dental clinics, which allowed the actual needs of users to be taken into account in the design process.

4. Results

4.1. The specific nature of dentistry and dedicated facilities

Currently, the aim is to create multifunctional centres where patients can access as many services as possible [15]. In such a place, patients can receive comprehensive care including diagnostics, treatment and follow-up visits covering various fields of dentistry. The range of services may include, among others, conservative dentistry (known as general dentistry), paediatric dentistry (also known as children's dentistry), endodontics (root canal treatment), implantology (replacement of missing teeth), prosthetics (restoring proper bite conditions), orthodontics (including the treatment of malocclusion and maxillofacial abnormalities), periodontology (dealing with the prevention and treatment of periodontal and oral mucosal diseases), dental surgery (surgical treatment of the oral cavity), dental physiotherapy (restoring muscle balance and improving the range of motion in the temporomandibular joints and mouth), dental speech therapy (supporting proper speech development and correcting speech disorders).

In cities, dental clinics usually operate in their basic form as private dental and/or orthodontic practices specialising in one or more dental specialisations. These are small facilities with one or more treatment rooms and a diagnostic area (X-ray). Some dental clinics also have an educational area in the form of a training room. University dental hospitals/dental centres affiliated with universities and also serving as educational institutions are much less common [16].

4.2. Functional zoning

Facilities dedicated to dentistry have simple functional and spatial layouts, in which a non-medical and a medical area can be distinguished. The non-medical area includes the entrance, waiting room with reception, toilets and an administrative area. The teaching zone may also be located nearby. The entrance zone with the waiting room is usually open plan, often clearly separated from the medical zone. It is a space where it is possible to create a less medical-looking interior design using natural materials, comfortable seating, and elements of greenery and art. The medical area with treatment rooms, sterilisation and diagnostic rooms differs from the non-medical area in its high degree of sterility and easily washable materials that are resistant to disinfectants. This area is usually dominated by white colours, emphasising the cleanliness and sterility of the space [16].

There are three types of treatment rooms. The first is a separate room with a single treatment chair. The second type is a single lockable room with several treatment chairs. The third type is an open-plan room with several treatment chairs separated by a partial wall [16]. In terms of preventing the spread of aerosols and cross-contamination, the safest type of room is a lockable room with a single treatment chair, which reduces the possibility of cross-contamination compared to the other two types of treatment spaces. The medical section also includes sterilisation and diagnostic rooms (for X-ray and CT examinations). Staff toilets, social rooms and changing rooms should be located close to this area.

A clear division into patient, treatment and auxiliary (sterilisation, diagnostics) zones, as well as technical areas (storage, waste, building maintenance) minimises the crossing of staff and patient paths and allows for separate flow of instruments, reducing the risk of cross-contamination (clean and dirty paths) and facilitating infection control.

4.3. Infection control, ventilation and safety in dental centres

The COVID-19 pandemic has highlighted the importance of aerosols generated during dental procedures [17]. Due to their specific nature, dental clinics are places of particular exposure to droplet-borne diseases, which can cause cross-contamination between staff and patients [18]. In dental clinics, it is essential to ensure hand hygiene, personal protective equipment and caution during medical procedures. The design and layout of the premises also play an important role in preventing infections and cross-transmission [19, 20]. The COVID-19 pandemic has hampered the work of dental clinics, which were places of increased risk of transmission. Limiting the spread of the virus makes it possible to break the chain of transmission, which requires special safety measures [21, 22, 23]. The greatest contamination

is caused by activities performed with the use of electrically powered devices [24]. Aerosols generated during dental procedures can travel considerable distances from the source, posing a risk of spreading infectious diseases. One way to reduce this phenomenon is through local exhaust ventilation (LEV), which reduces contamination from aerosols and droplets generated during dental procedures by at least 90% [25].

Guidelines for the prevention and control of dental infections developed by experts are an important element in standardising work and improving the functioning of dental centres [26, 27]. Preventive control involves many elements and procedures. In the context of space design, HEPA air purification filters and heating, ventilation and air conditioning (HVAC) systems should be highlighted in order to increase filtration efficiency [28]. In addition, adequate air exchange in the treatment room is necessary, assuming approximately 6–12 air exchanges per hour, depending on the procedures used and local conditions. Aerosol-generating procedures are the main source of potential transmission, so it is important to design the treatment room correctly, with appropriate air supply and exhaust locations and the elimination of dead air zones [23]. Dental procedures generate contaminants, which necessitates the use of personal protective equipment (including respiratory, face and body protection during procedures) and the need to clean the areas around the patient [29].

4.4. Non-medical areas in the context of patient comfort

There are differences between how staff and patients perceive the space in a dental facility. Staff pay more attention to factors that affect long-term comfort and the performance of their duties [11]. Patients, on the other hand, focus primarily on visual and emotional aspects, such as interior aesthetics, cleanliness, smell and a sense of security.

The waiting area in dental clinics, as a stressful place for patients, requires positive elements that distract attention and improve comfort (Figs. 1–2). According to research, specific interior features can help alleviate patient stress. These elements include good lighting, a suspended ceiling with natural elements, large windows with views of greenery, indoor potted plants, curved wall shapes, natural materials and a variety of seating options [12]. In addition, elements of a healing environment, such as appropriate acoustics, are important. The waiting area with reception should help reduce patient stress by creating a friendly, non-medical atmosphere. The basis for actions in this direction is to create a comfortable, well-lit interior that allows for distance and privacy. Studies show that a well-designed waiting room can reduce the patient's perceived stress and improve their experience of visiting the facility [12].

Figure 1. Design of a dental centre in Lublin. From the left: main entrance to the facility, representative entrance area with reception and atrium, detail of the visual identification system. *Source: W. Błasiak, 2025, engineering thesis supervised by R. Strojny*

A separate issue is the design and furnishing of clinic spaces for patients of developmental age, which affects their feelings and behaviour. A waiting room designed with this group of users in mind must provide a friendly environment with colourful furniture, toys, etc., arranged in bright, subdued colours with warm white lighting [30].

Figure 2. Design of a dental centre in Lublin – non-medical areas. From the left: waiting room for patients in the atrium area, waiting room for children. *Source: W. Błasiak, 2025, engineering thesis supervised by R. Strojny*

4.5. The specifics of designing treatment rooms

Dentists are exposed to musculoskeletal disorders associated with the specific nature of their profession [31]. For these reasons, among others, it is very important to ensure the ergonomics of treatment stations with short movement sequences, space for electronic documentation at the unit, the possibility of easily isolating the treatment area, adequate lighting and ergonomic positioning of equipment [23].

The design of a dental office is a way of conveying information about the facility and its values to patients, so it should take into account the ever-increasing expectations of patients regarding comfort and a pleasant environment [32]. Dental offices are equipped with: a dental unit, all the necessary equipment for performing procedures, an assistant's chair, storage space, chairs for medical staff, hand washbasins, a single-compartment metal sink with a tub for immersion disinfection of large dental instruments and a box for disinfecting small rotary instruments. Another important element is the division of bins into medical waste, other medical waste, municipal waste and a container for sharp waste [33]. The workspace in the surgery must not be too small and must not contain too many exposed objects in order to limit the elements on which microorganisms can settle. Consulting rooms and other spaces in the dental centre should be accessible to people with disabilities.

An ergonomic workstation requires designated space for the dentist, assistant and patient. Treatments are performed by the dentist and one assistant. In dental practice, the division and location of these zones refers to the so-called ergonomic clock [34]. Analysing the case of a right-handed dentist's zone, it is designated in such a way as to have a direct view of all tooth surfaces, i.e. from 9 to 12 o'clock. In accordance with the four-handed working principle, the dentist focuses on performing the procedure, while the assistant ensures smooth operation by preparing the appropriate instruments. They use a panel with a suction device and a saliva ejector, as well as a console with rotary instruments, which is why their zone is designated from 12 to 3 o'clock (Fig. 3).

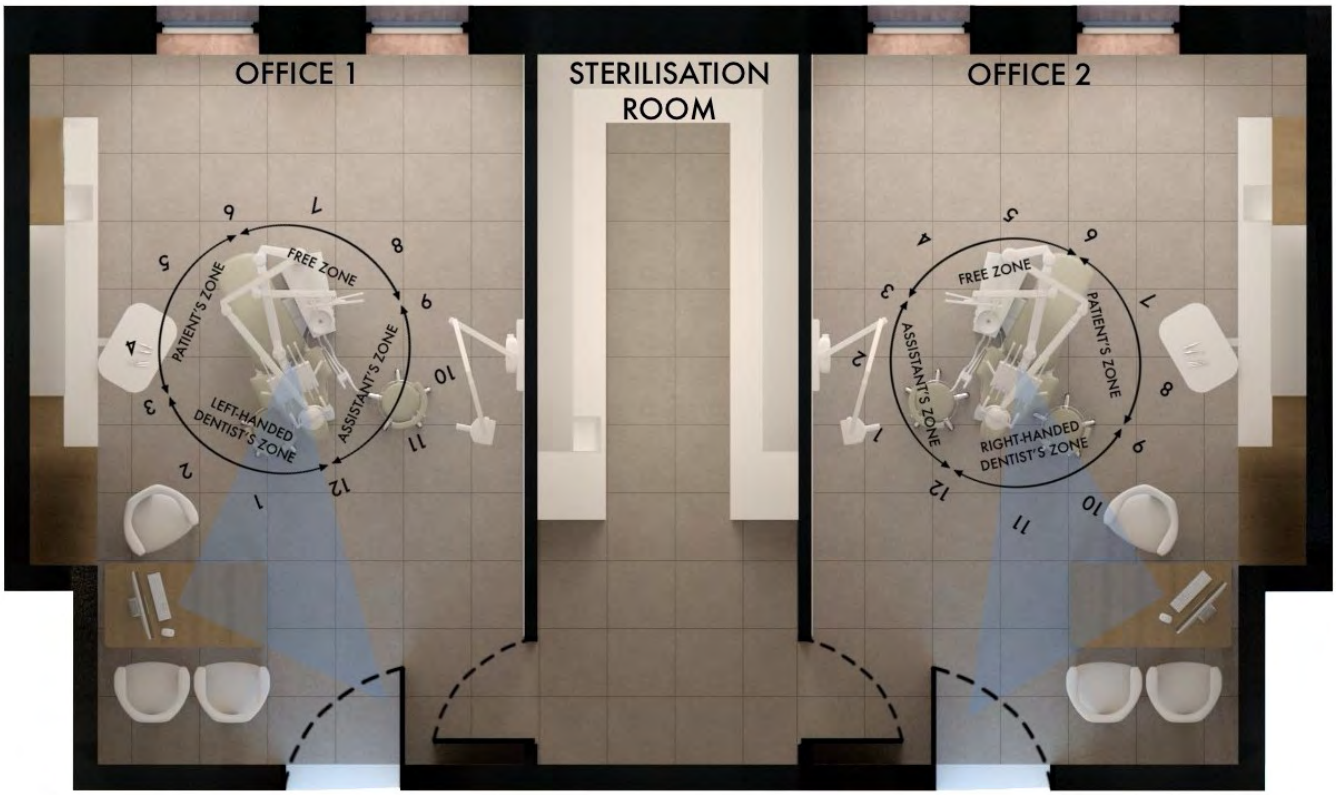

Figure 3. Design of a dental centre in Lublin – concept of an ergonomic dental office with a direct connection to the sterilisation zone. *Source: W. Błasiak, 2025, engineering thesis supervised by R. Strojny*

Patients entering the office are directed straight to the dental chair or to the consultation area where they have a pre-treatment consultation with the dentist. The unit is positioned in the office so that there is free space on both sides and behind the patient's head [34]. The door to the office and the consultation desk should be located between 9 a.m. and 12 p.m. In this way, the patient's area is marked by a "triangle" whose vertices are formed by the dental chair, the entrance door and the consultation station.

Separating the zones for users of the surgery allows you to designate communication routes for each of them and ensure that they do not intersect. This can increase staff efficiency and patient comfort. The free space between 3 and 6 o'clock can be used for necessary treatment equipment such as a microscope (mobile or attached to the wall or ceiling), spot X-ray, intraoral scanner, and hygiene carts. It is advisable for the dental chair to face the window, at a certain distance from the walls, as it must be accessible from all sides and allow for position adjustment [35]. Storage units, as well as units housing items such as sinks, soap dispensers and disposable materials, should be located on the medical staff side, at 12 o'clock, so that both the dentist and the assistant have easy access to them. Modern solutions allow the use of a pull-out worktop with an instrument tray instead of a traditional wheeled assistant.

4.6. Design issues for people with disabilities and the elderly

The design of dental offices for people with disabilities requires consideration of the specific needs of patients with limited mobility, taking into account the individuality of each case. In clinics for patients with special needs, appropriate equipment is crucial. It should allow for easy adaptation of the equipment, for example, to patients using wheelchairs, walkers or crutches. It is also important that the layout of the clinic itself allows doctors to work comfortably. In the case of wheelchair patients, doctors often find it impossible to transfer them to the dental chair, as a result of which they have to work facing the patient, adapting their treatment techniques to the individual needs of the patient [36].

It is recommended to change the "movement vector" – instead of forcing patients to travel to specialists, all consultations and procedures should be organised on site, which reduces the burden on the patient and limits contact with transport barriers [36]. Another important aspect of office design is the elimination of architectural barriers. Difficult access to the building, narrow passageways, high thresholds and doors that open in the wrong direction can be an obstacle for patients with physical disabilities. The appropriate size of the surgery should allow for freedom

of movement for people in wheelchairs or on stretchers and enable the presence of a carer for the disabled person, whose participation in treatment is often crucial due to the need for psychological support and assistance in moving around, but also to gather information from the doctor for proper subsequent home care [36].

When designing for older people, it is essential to take into account the mobility difficulties that often accompany advanced age and affect visits to specialists. It is also important to adapt the patient's position and the doctor's work organisation to the specific requirements of seniors. Due to physical limitations, older patients may have difficulty remaining in a lying position for long periods of time, which can lead to fatigue and discomfort. It is therefore recommended that these patients be allowed to remain in a semi-reclining or sitting position, avoiding excessive tilting of the head backwards, which could cause shortness of breath. During procedures, especially those involving water, the amount of water in the patient's mouth should be monitored to prevent choking. It is also recommended that visits be shorter but more regular, which helps to avoid excessive fatigue [34]. The appropriate approach of the medical team is also important. Each admission of a patient with limited mobility requires the commitment and dedication of more time by all staff.

In the United States, the ADA (Americans with Disabilities Act) guidelines are in place to ensure equal access to services for people with disabilities, including in medical facilities such as dental practices. According to these rules, every dental office should be designed and run in a way that is friendly to all patients. This includes, among other things, accessible parking spaces, a threshold-free entrance and wide access paths. The reception desk should have a lowered countertop and adequate manoeuvring space, and the waiting room should have comfortable, varied seating. Treatment rooms must have space for wheelchair manoeuvring and an adjustable chair to facilitate patient transfer. Toilets must be equipped with handrails, low washbasins and wide doors to allow for easy use. Appropriate signage and communication are also important, e.g. sign language interpreters, subtitles or large print materials. Staff should be trained in dealing with patients with disabilities and be familiar with the procedures for providing the necessary facilities [37].

4.7. The specific nature of an orthodontic surgery with a technician's laboratory

A common solution is to equip the orthodontic office with two units – one for the orthodontist, where the treatment plan is discussed with the patient based on a prior orthodontic examination and bite assessment, the other is used by the assistant to take impressions for diagnostic plaster models and to change ligatures (orthodontic elastics) during check-ups in the case of fixed appliances.

This is complemented by a room for the dental technician. This is where plaster models, orthodontic appliances, as well as dentures and other prosthetic restorations, such as implants, veneers and crowns, are made. The main piece of equipment in the laboratory is the prosthetic table at which the technician works. The necessary equipment includes a polisher and a prosthetic sandblaster, as well as a plaster cutter, a casting machine and a furnace. In addition to these, there are many other devices that make up the equipment of a dental technician's laboratory. Their appropriate selection depends on the technique used and the materials used to make specific elements.

The use of state-of-the-art computer technology in the design and manufacture of various types of prosthetic restorations is becoming increasingly popular. CAD/CAM devices are used for this purpose, e.g. laboratory scanners, milling machines and 3D printers [38]. Modern equipment is precise and significantly facilitates and optimises the production process, as well as allowing the product to be tailored to the individual needs of each patient.

Due to the significant amount of materials used (acrylic resins, wires, composites, specialised adhesives) and the need to store impressions or plaster models, such a space requires a large amount of storage space.

4.8. Dental physiotherapy and speech therapy room

The basic equipment of a physiotherapy room is a massage and rehabilitation table, needed to perform manual therapy on the face, neck and back. A mirror is also essential, allowing the patient to control their facial movements and observe the course of the exercises. The devices used in physiotherapy include apparatus for electrostimulation, ultrasound therapy and laser therapy [35]. The equipment also includes a kinesiotaping kit, as well as tapes and balls for exercising the muscles of the face and neck. For dental problems, physiotherapy may also include exercises for the back, neck and shoulder muscles, which affect the correct positioning of the head and jaw, so optional equipment includes wall bars, which can be useful for exercises on overall body posture.

In the case of individual therapy in a speech therapy room, the users of the room will be the patient, the therapist and 2 parents/guardians. When dealing with group therapy, space is needed for up to 4 patients, a therapist and a possible trainee. The speech therapy office should be bright and spacious to allow for free space for movement and breathing exercises. Various types of mirrors are among the necessary equipment [39].

4.9. Dental surgery office

Dental surgery rooms are usually larger than standard dental offices. This is due to the need for space for additional specialised equipment and the ability of staff to move freely during more complex surgical procedures. The equipment includes surgical instruments (e.g. surgical drills, scissors, extraction forceps), specialised lamps, surgical suction devices, microscopes and, in the case of more invasive procedures, equipment for monitoring the patient's vital signs [40]. More and more people are choosing to undergo dental anaesthesia for more serious procedures, which minimises discomfort, pain and stress. In such cases, it is necessary to consult an anaesthesiologist in advance, who will assess the possibility of using general anaesthesia and its dosage.

In order to perform surgery under anaesthesia, an anaesthesiology team is required to safely administer general anaesthesia and monitor the patient during the operation, as well as a dental team to perform the actual procedure. Due to the number of people involved in the process at any one time, sufficient space is required for each of them to ensure that the procedure is as efficient and effective as possible and to prevent unnecessary collisions. After the procedure under anaesthesia, the patient is transferred to the recovery room, where they remain under the care of medical staff and an anaesthesiologist until the anaesthetic drugs have completely worn off.

4.10. The specifics of designing diagnostic, sterilisation and auxiliary areas

In dental radiology, there are three basic types of X-ray machines: intraoral, panoramic and CBCT (three-dimensional) tomographs. The most common device in dental offices is the intraoral machine, which allows you to obtain the images necessary for making a diagnosis, planning treatment and monitoring its progress. This type of equipment is standard in every dental surgery, regardless of specialisation. Panoramic devices are used, among others, in conservative dentistry, orthodontics and periodontology. They provide a broad view of the entire oral cavity, including the upper and lower jaws, sinuses and teeth, which allows for the assessment of more complex cases, such as advanced periodontal disease, developmental defects and neoplastic changes. CBCT is a technology that enables three-dimensional imaging of anatomical structures – teeth, bones, nerves and soft tissues. It is a particularly useful tool in pre-operative diagnostics, used mainly by specialists in maxillofacial surgery and implantology [41]. Rooms used for X-ray imaging must be suitably adapted, including protection against light.

In addition to the diagnostic area, dental centres must have a sterilisation area. The layout of the sterilisation room should be designed to ensure a one-way flow of materials at every stage of the technological process – from the moment the contaminated materials are received until they are released as sterile. It is important to maintain the technological sequence – each activity must be performed in the appropriate place for that activity. This is necessary to prevent the risk of recontamination of instruments that have already been cleaned [42].

The technological sequence consists of (Fig. 4):

1. contaminated materials section – unloading, prepared for cleaning and disinfection,
2. machine or manual washing section,
3. disinfection section,
4. clean materials section – drying and maintenance, and packaging before sterilisation,
5. proper sterilisation,
6. sterile materials section – cooling of instruments and their storage [43].

The proper functioning of treatment rooms outside the sterilisation zone requires a compressor room. The operation of devices on the doctor's panel and assistant's panel is possible thanks to connection to a compressor and suction pump. Due to the noise generated (in some cases up to 70 dB), it is advisable to install these devices in a separate room. Proper ventilation must also be ensured, as both machines generate heat. The pump must also be able to expel used air to the outside so that the compressor does not suck it in and deliver it to the patient's mouth [44].

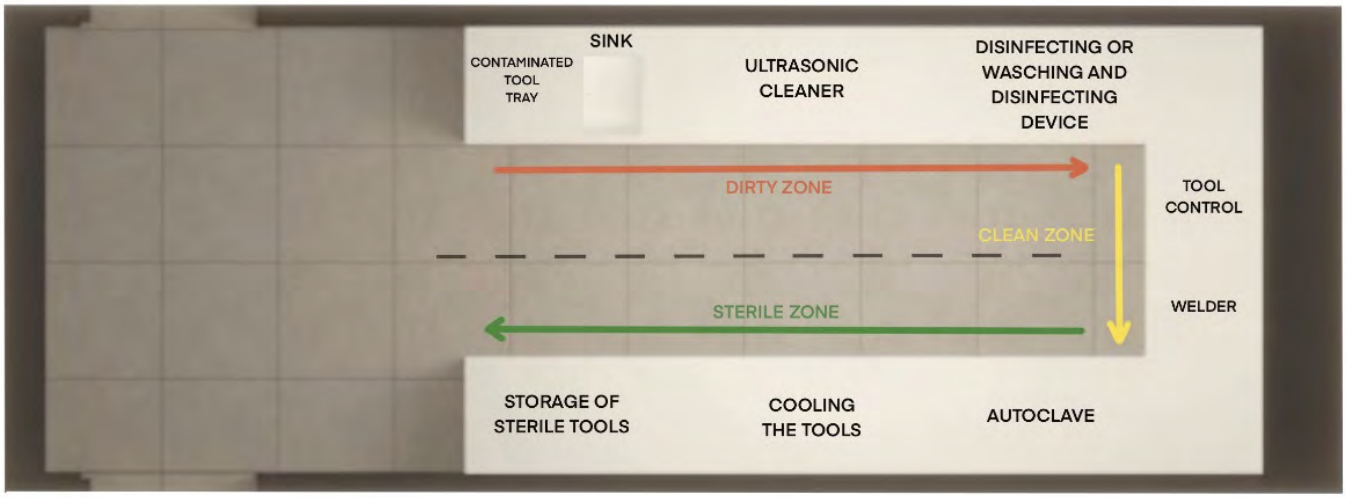

Figure 4. Design of a dental centre in Lublin – concept of the sterilisation zone. *Source: W. Błasiak, 2025, engineering thesis supervised by R. Strojny*

4.11. Teaching area in the dental centre

The training room should be equipped with devices that enable students to practise using dental tools, which is crucial for developing their manual skills. In the last decade, dental simulation technology has undergone a significant evolution – from classic phantoms to simulators using virtual reality. This makes it possible to practise without physical models. SIMtoCARE Dente, developed by SIMtoCARE B.V., and SimoDont, developed by Moog Inc., are particularly popular. Thanks to realistic 3D visualisation and haptic systems, they provide an opportunity to familiarise oneself with realistic working conditions and learn complex treatment procedures [44].

4.12. Materials and surfaces

In dental clinics, hygiene, ease of maintenance and durability are key factors in the selection of materials, while also taking into account patient comfort (Fig. 5). Materials in medical areas must be non-porous, easy to clean and resistant to frequent exposure to strong disinfectants. It is also necessary to minimise gaps, joints and hard-to-reach surfaces. Laminates and Corian are used for wall finishes in such spaces, providing smooth, easy-to-clean surfaces, as well as specialised paints and vinyl floorings that meet strict hygiene standards. Rigid fibreglass panels are also popular, particularly for their antibacterial properties. In addition to sanitary functions, increasing attention is being paid to interior aesthetics in order to create a friendly and less institutional environment [16].

Copper-containing metals have antiviral properties. Its alloys, such as brass and bronze, have antimicrobial properties. Copper is an excellent material for use on frequently used surfaces such as door handles, countertops and cladding materials. Copper flooring, walls or copper paint can purify the surrounding air [19]. Sinks and taps should minimise hand contact, e.g. through foot-operated or hand-operated taps with automatic soap dispensers [20].

When selecting materials, it should also be taken into account that the radiology room must be adequately protected against X-ray radiation. For this purpose, high-density materials such as lead or barium sulphate are used, which effectively block radiation. The walls are usually made of plasterboard covered with a layer of lead, and all gaps, joints and expansion joints must be precisely sealed. Additional protection is provided by specialised doors and windows with lead glass, which prevent radiation from penetrating [45].

4.13. Waste management

A dental clinic should have a separate room for storing medical waste, with smooth, washable surfaces, adequate ventilation and a separate entrance secured against access by unauthorised persons and pests. Waste should be removed within 72 hours to a storage facility where the temperature does not exceed 10°C, and the maximum storage time is 30 days [46]. Waste management should include segregation, decontamination, deformation reduction, transport and

final disposal. Types of medical waste, containers and waste boxes should be properly labelled, and infectious waste must be separated from sharp, toxic, hazardous and stationary waste [20].

To prevent clean routes from crossing waste transport routes, a pneumatic tube system can be used. It works by sending special capsules through a network of pipes using pressure differences, allowing medical waste to be transported directly from the point of origin to the storage location. This allows for fast, contactless waste transport and eliminates the need for manual transport through passageways.

This technology is increasingly used in modern medical facilities, where it is part of an integrated waste management system. An example is the solutions developed by Envac, which has developed automatic pneumatic waste transport systems to replace gravity chutes in hospitals. Traditional chutes had a vertical design, which encouraged the accumulation of waste, the formation of blockages and the growth of bacteria and unpleasant odours. In the pneumatic system, waste is transported through a closed network of pipes using pressure differences, which eliminates the risk of material stagnation and staff contact with infectious waste [47].

Figure 5. Design of a dental centre in Lublin – concept of a dental office. *Source: W. Błasiak, 2025, engineering thesis supervised by R. Strojny*

5. The concept of a comprehensive dental centre in Lublin

The L-shaped floor plan of the building allows the layout to be divided into a right and left wing with specific functions on each floor. In the design, the "heart" of the facility is a common area in the form of a waiting room with an atrium lit from above by a skylight (Fig. 6).

Upon entering the building from the east, the user finds themselves in a representative hall with a reception and waiting room. The right wing of the centre's ground floor is the educational part for dentistry students. It houses a lecture hall for 20 students and a training room with modern simulators. The left wing is designated for technical services and office staff. Both wings have access to a green courtyard.

On the first floor, there is a surgery room adapted for disabled or elderly people, where treatment can be tailored to the individual needs of the patient. The right wing is dedicated to the care of the youngest users. There are two paediatric dentistry (pedodontics) offices, as well as one dental speech therapy office, where appointments can be conducted individually or in groups. A small corner for children with toys and books has also been set aside to make the visit to the specialists more pleasant for the youngest patients and minimise the stress associated with it. The left

wing is part of the dental surgery with two treatment rooms. One of them allows for treatment under anaesthesia – it has been connected to the recovery room by sliding doors. This part also houses an anaesthesiologist's office, whose presence is necessary when performing procedures under general anaesthesia.

Each floor has a staff room and a block of bathrooms, including toilets adapted for disabled people (Fig. 7).

Figure 6. Design of a dental centre in Lublin. From the left: the shape of the building, front façade. *Source: W. Błasiak, 2025, engineering thesis supervised by R. Strojny*

Based on five in-depth interviews, several conclusions can be drawn regarding the functioning of sterilisation rooms in dental centres. Respondents unanimously emphasised that the key factor influencing the efficient organisation of work is the number of offices served by a single sterilisation room. When it serves too many offices, organisational chaos ensues. In turn, according to the interviewees, the best solution is a situation where one sterilisation room serves a maximum of two surgeries – then the process runs more smoothly.

In addition, the interviewees pointed out the problematic location of the sterilisation unit in relation to the treatment rooms. It is disadvantageous when it is necessary to walk through main passageways, waiting rooms or public areas with the instruments. The optimal solution would therefore be to design the sterilisation room in the immediate vicinity of the treatment rooms, which would enable fast, safe and hygienic transport of instruments.

Taking the above conclusions into account, the sterilisation rooms in the dental centre have been designed in a modular way so that they can be accessed from any two treatment rooms. This layout makes it easier to maintain cleanliness and efficiently transfer instruments for disinfection and sterilisation, minimising the need to transport them through public corridors. In addition, the entrances to the sterilisation rooms leading directly from the treatment rooms make this area accessible only to medical staff. This reduces the risk of accidental intrusion by unauthorised persons.

The design of the dental centre includes a pneumatic mail system. This solution is a modern and effective way of transporting medical waste generated in the offices to the storage area without the need for staff to carry it directly through the corridors. The operation of the pneumatic mail system in the designed building is shown in the diagram (Fig. 8).

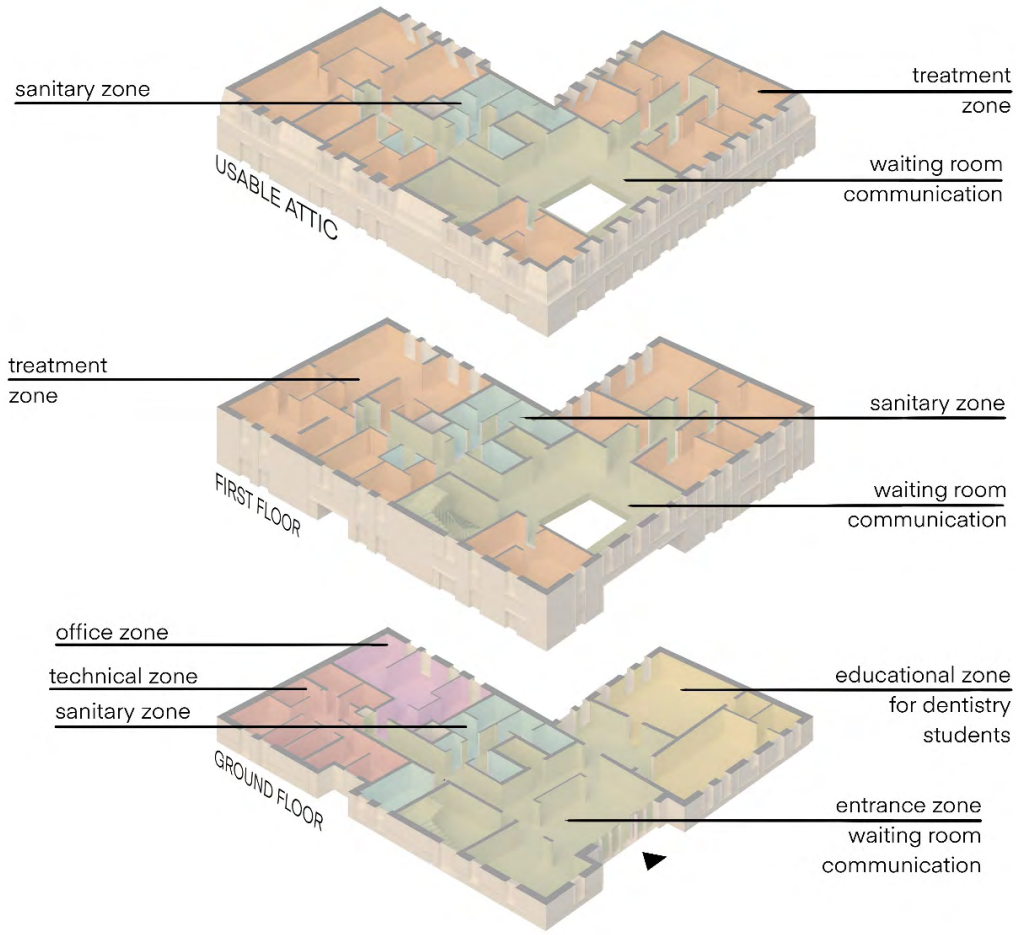

Figure 7. Design of a dental centre in Lublin – diagram showing the functional layout of the facility. *Source: W. Błasiak, 2025, engineering thesis supervised by R. Strojny*

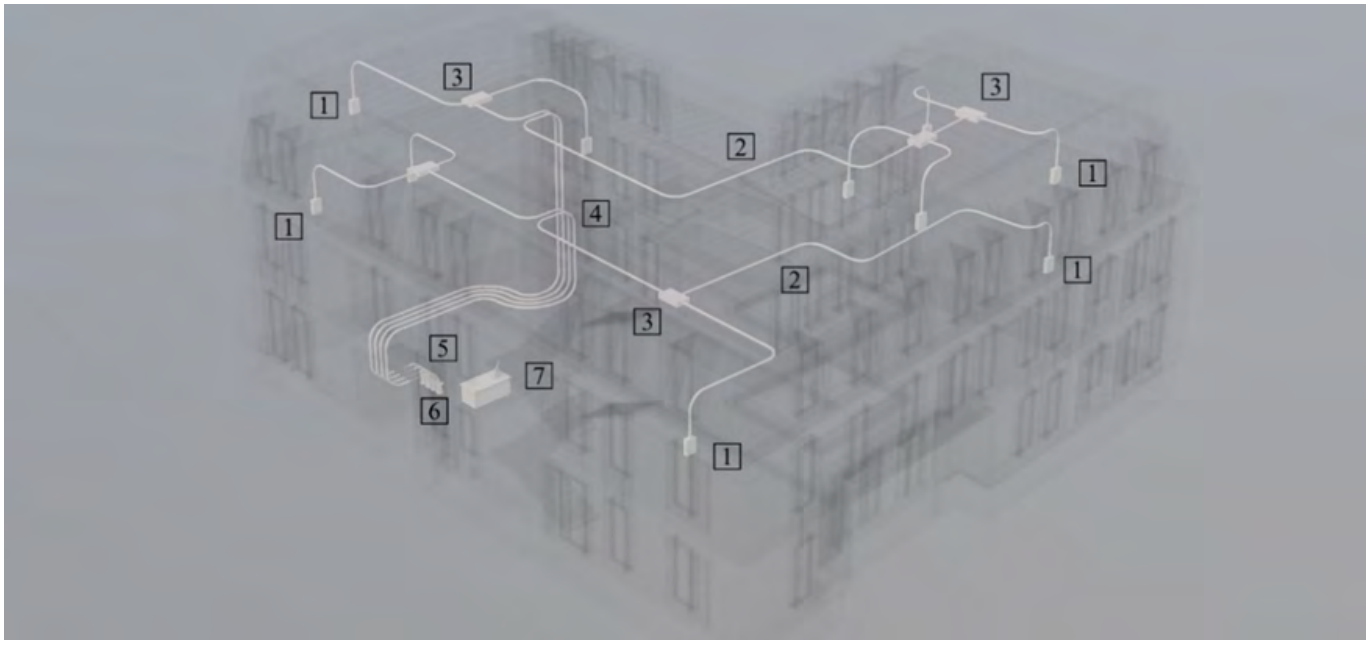

Figure 8. Design of a dental centre in Lublin – diagram of the pneumatic tube system in the facility. (1) Transmitting station in the office; (2) Transport tube; (3) Switch; (4) Pipes in the technological riser; (5) Receiving station in the pneumatic mail machine room; (6) Blowers generating pressure in the transport pipes; (7) Control computer. *Source: W. Błasiak, 2025, engineering thesis supervised by R. Strojny*

Contaminated material in a given office is placed in a capsule, which is then placed in the sending station. The container is transported through a network of pipes with a diameter of 110 mm [48]. The installation is hidden behind a suspended ceiling, which makes it invisible to patients of the dental centre. Inspection hatches in the ceiling allow for

easy access and repair in case of failure. There are switches at intersections to guide it in the right direction. Installations from each floor are collected in a vertical shaft, from where they are further transported down to the receiving station in the pneumatic mail machine room. At its destination, the capsule moves downwards under its own weight and ends its journey on the receiving rail. The machine room also houses a control computer, which determines the route to be taken by a specific container and manages the settings of the blowers and switches.

6. Summary and conclusions

The design of modern dental clinics requires an interdisciplinary approach, combining knowledge of architecture, environmental engineering, ergonomics, environmental psychology and infection control (Table 1). A review of the current literature indicates that the effectiveness and safety of clinical spaces increasingly depends on the quality of the indoor environment — in particular, ventilation systems, space organisation and interior material properties.

Table 1. Key elements in the design of a dental centre. *Source: authors*

No.	Element	Purpose/effect
1	Integrated design	A holistic approach to functionality and safety – an effective dental centre requires cooperation between architects, HVAC engineers, epidemiologists and ergonomists as early as the concept stage.
2.	CFD simulations and air flow analysis	Optimisation of ventilation and reduction of pathogen transmission.
3.	Healing environment and biophilic design	Increased comfort, reduced stress for patients and staff.
4.	Functional flexibility and modularity of the layout	Adapting the facility to changing technological and epidemiological needs.
5.	Evidence-based design	Combining medical, environmental and psychosocial aspects into a coherent spatial system.
6.	Accessibility and inclusivity	Ensuring accessibility for people with disabilities and mobility limitations.
7.	Functional zoning	Separation of clean, dirty and communication zones to maintain hygiene and safety.
8.	Antimicrobial materials	Increased hygiene and durability of surfaces in clinical spaces.

At the same time, the concept of a healing environment is becoming increasingly important in the design of dental facilities, including elements such as access to natural light, the introduction of plants, noise control and the selection of colours and materials that help reduce stress. Contemporary research confirms that a properly designed clinical environment reduces patients' emotional tension and increases staff comfort, which translates into the quality of services and the perception of the facility.

In terms of ergonomics and work efficiency, clear functional zoning, shortening of communication routes and separation of central sterilisation zones serving groups of offices are key. The modular structure of the facility allows for future transformations and adaptation to technological changes without interfering with the building's structural layout.

The assumptions adopted in the original conceptual design – including the use of biophilic design strategies and sustainable functional zoning – indicate that a modern dental centre can be an example of evidence-based design. This approach not only improves user safety and comfort, but also increases the resilience of medical infrastructure to future epidemic threats.

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Projektowanie architektoniczne współczesnych klinik stomatologicznych na podstawie badań naukowych – studium przypadku

Streszczenie: Współczesne kliniki stomatologiczne stanowią złożone obiekty medyczne, w których efektywność funkcjonalna, bezpieczeństwo epidemiologiczne i komfort użytkowników muszą być w równym stopniu zintegrowane w procesie projektowym. W ostatnich latach, zwłaszcza po pandemii COVID-19, wzrosło znaczenie rozwiązań architektonicznych wspierających kontrolę aerozoli oraz optymalizację wentylacji pomieszczeń zabiegowych. Celem niniejszego opracowania jest analiza aktualnych trendów i wyników badań naukowych dotyczących projektowania środowiska stomatologicznego w kontekście zasad evidence-based design (EBD) oraz przedstawienie koncepcyjnego modelu centrum stomatologicznego w Lublinie, opartego na zintegrowanym podejściu architektoniczno-technicznym. Metodologia obejmuje analizę literatury, identyfikację kluczowych aspektów projektowych oraz opracowanie modelowej koncepcji centrum stomatologii na podstawie literatury i wywiadów pogłębionych z personelem medycznym jednej z klinik stomatologicznych w Lublinie. Wyniki analizy wskazują, że projektowanie klinik stomatologicznych wymaga podejścia zintegrowanego, łączącego zasady higieniczno-epidemiologiczne z czynnikami psychologicznymi i ergonomicznymi. Kluczowe znaczenie mają: właściwy układ wentylacji i oczyszczania powietrza, centralne strefy sterylizacji, modułowy układ gabinetów oraz zastosowanie strategii healing environment, biophilic design i rozwiązań akustycznych poprawiających komfort użytkowników.

Słowa kluczowe: projektowanie klinik stomatologicznych, centrum stomatologiczne, projektowanie oparte na dowodach