

إدارة وتطبيقات عيادات الأسنان في مدينة الرياض  
**Dental Clinics Management and Applications in Riyadh City**

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## **Abstract**

The management and spatial distribution of private dental clinics in Riyadh, Saudi Arabia, is essential for ensuring equitable access to dental healthcare services. This study aimed to evaluate the operational aspects and geographic placement of private dental healthcare facilities (PDHFs) in Riyadh in relation to population density and accessibility. Data were collected from the Ministry of Health, covering 632 active PDHFs, including their location, operability, and dentist demographics. The study utilized Quantum Geographic Information System software for spatial analysis and correlated findings with population density data. Results revealed an uneven distribution of PDHFs, with clusters in high-density sub-municipalities such as Olaya and Maather, where PDHF-to-population ratios were 1:4566 and 1:4828, respectively. In contrast, underserved areas lacked sufficient facilities, with only 36.3% of Riyadh's total area within a 1 km buffer zone of a PDHF. Additionally, non-Saudi dentists constituted 86.66% of the workforce, predominantly in general dentistry, with a significant gender disparity favoring male dentists (63.97%). Conclusions highlight the need for strategic planning to address geographic disparities, increase female representation, and improve accessibility in underserved areas. These findings can guide policymakers and stakeholders in optimizing dental healthcare services and equitable resource allocation.

**Keywords:** dental clinics, geographic information system, accessibility, population density, healthcare management, Riyadh, Saudi Arabia.

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### List of Terminology

| Term                                                                | Definition                                                                                                              |
|---------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>GIS (Geographical Information System)</b>                        | A system used to capture, store, analyze, manage, and present spatial or geographic data.                               |
| <b>PDHFs (Private Dental Healthcare Facilities)</b>                 | Dental clinics or practices that are privately owned and provide dental services to the public.                         |
| <b>KSA (Kingdom of Saudi Arabia)</b>                                | The country in which Riyadh is located.                                                                                 |
| <b>MOH (Ministry of Health)</b>                                     | The governmental body responsible for overseeing the health sector in Saudi Arabia.                                     |
| <b>QGIS (Quantum Geographic Information System)</b>                 | A specific type of GIS software used for spatial analysis and mapping.                                                  |
| <b>km<sup>2</sup> (Square kilometers)</b>                           | A unit of area measurement commonly used to quantify the size of regions or territories.                                |
| <b>FTE (Full-Time Equivalent)</b>                                   | A unit of measure that represents the workload of an employed person, equivalent to a full-time employee's hours.       |
| <b>MNGHA (Ministry of National Guard-Health Affairs)</b>            | A governmental body that provides healthcare services to the National Guard and the wider public in Saudi Arabia.       |
| <b>KAIMRC (King Abdullah International Medical Research Center)</b> | A medical research institution under the Ministry of National Guard-Health Affairs in Saudi Arabia.                     |
| <b>IRB (Institutional Review Board)</b>                             | A committee that reviews and approves research studies involving human subjects to ensure ethical standards and safety. |

### **List of Abbreviations**

|                 |                                                      |
|-----------------|------------------------------------------------------|
| GIS             | Geographical Information System                      |
| PDHFs           | Private dental healthcare facilities                 |
| KSA             | Kingdom of Saudi Arabia                              |
| MOH             | Ministry of Health                                   |
| QGIS            | Quantum Geographic Information System                |
| km <sup>2</sup> | Square kilometers                                    |
| FTE             | Full time equivalent                                 |
| MNGHA           | Ministry of National Guard-Health Affairs            |
| KAIMRC          | King Abdullah International Medical Research Center. |
| IRB             | Institutional Review Board                           |

## **Chapter 1: Research plan**

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### **1.1 Introduction**

Accessibility is a cornerstone of achieving optimal healthcare delivery and is one of the five main characteristics required for effective access to care. Defined as the ability of the population to receive and utilize healthcare services when needed, accessibility encompasses dimensions such as affordability, availability, accommodation, and acceptability, alongside geographic accessibility [1,2]. Geographic accessibility specifically focuses on the ease with which clients can physically reach healthcare providers, measured by factors like distance and travel time [3,4]. While access to healthcare services is essential for promoting a high quality of life, achieving equitable access is often hindered by several barriers, including lack of awareness regarding the spatial distribution of services, challenges for private healthcare investments, and inadequate understanding of geographic and population dynamics.

In the context of oral health, dental caries and periodontitis are among the most prevalent diseases globally, with significant implications for public health. Studies highlight the high prevalence of dental caries in Saudi Arabia, particularly among children, where rates exceed 80% in some age groups [5,6]. Despite the preventable nature of dental caries, a lack of accessibility to dental care services continues to contribute to its rising prevalence. Regular dental visits and early detection of oral diseases are critical for improving outcomes and enhancing the population's overall health quality. The Saudi Ministry of Health (MOH) has prioritized the development of dental services, emphasizing prevention, early intervention, and awareness initiatives. However, disparities in accessibility to dental care persist, particularly in urban hubs like Riyadh, where geographic distribution and population density present unique challenges.

Riyadh, as one of the fastest-growing cities globally, has experienced rapid urbanization and population growth, with a population exceeding six million as of 2016 [7]. While the city boasts over 650 dentists working in government facilities and more than 3,000 dentists in private clinics, there remains limited data regarding the spatial distribution, demographic characteristics, and specialization of these practitioners [8]. This lack of information impacts decision-making for both health authorities and private investors, potentially leading to oversaturation in some areas and underserved populations in others.

Addressing these disparities requires comprehensive mapping and analysis of dental healthcare facilities in Riyadh, focusing on their geographic distribution relative to population density and socioeconomic factors. This study aims to fill the gap by evaluating the spatial distribution of private dental healthcare facilities (PDHFs) in Riyadh. By assessing PDHF-to-population ratios and analyzing correlations between PDHFs and variables such as area size, population, and income, this research seeks to identify overserved and underserved areas, thereby providing valuable insights for health authorities and private sector stakeholders. The findings aim to contribute to the strategic planning of dental care services, ensuring more equitable access and improving the overall well-being of Riyadh's residents.

## **1.2 Research Problem**

The rapid urbanization and population growth in Riyadh, the capital city of Saudi Arabia, have brought about significant challenges in ensuring equitable access to healthcare services, particularly in the field of dentistry. As the population exceeds six million, the demand for dental care services has increased, yet the distribution of private dental healthcare facilities (PDHFs) remains uneven across different regions of the city. Despite the availability of over 630 private

dental clinics, many areas, especially those in the outer districts and suburban neighborhoods, continue to experience limited access to essential dental care services.

This uneven distribution of PDHFs is further exacerbated by various factors, including socio-economic disparities, population density, and the geographical barriers that impact individuals' ability to access timely dental care. In addition to these physical access issues, the dental workforce in Riyadh exhibits a significant imbalance, with a high proportion of non-Saudi dentists, as well as a gender disparity that favors male professionals. These factors contribute to the overall challenge of achieving equitable and accessible dental care for all residents.

Given the critical role that oral health plays in overall public health, there is an urgent need to understand how the spatial distribution of PDHFs correlates with population density, accessibility, and socio-economic factors. Addressing these gaps in access requires a comprehensive evaluation of the operational aspects of PDHFs in Riyadh, including their geographic placement, workforce composition, and the population dynamics in different areas. This research seeks to identify the underserved areas in Riyadh, assess the availability and accessibility of dental care in relation to population distribution, and provide evidence-based recommendations for strategic planning in dental healthcare services.

The research problem, therefore, focuses on understanding the factors that contribute to the inequitable distribution of dental healthcare facilities in Riyadh, with the goal of improving access to dental care services for all residents, regardless of their geographic location, income level, or demographic characteristics.

### **1.3 Research Hypotheses**

#### **1. Hypothesis 1: Uneven Distribution of Private Dental Healthcare Facilities**

- There is a significant geographical disparity in the distribution of private dental healthcare facilities (PDHFs) in Riyadh, with high-density areas such as Olaya and Maather having a higher concentration of clinics compared to lower-density areas.

## **2. Hypothesis 2: PDHF-to-Population Ratio**

- The PDHF-to-population ratio is significantly lower in underserved areas of Riyadh compared to high-density urban areas, leading to reduced accessibility to dental care for residents in those regions.

## **3. Hypothesis 3: Accessibility and Buffer Zones**

- A smaller proportion of Riyadh's total area is within a 1 km buffer zone of a PDHF, suggesting that geographic accessibility to dental care is limited in many parts of the city, particularly in suburban and peripheral areas.

## **4. Hypothesis 4: Dentist Demographics**

- Non-Saudi dentists make up a disproportionate share of the workforce in Riyadh's private dental healthcare facilities, with a significant gender disparity favoring male dentists, which may influence the overall quality and accessibility of dental care.

## **5. Hypothesis 5: Socio-Economic Factors and Access**

- Socio-economic factors such as population income levels and district characteristics significantly correlate with the availability of private dental healthcare facilities in Riyadh, with wealthier areas having better access to dental care.

## **6. Hypothesis 6: Impact of Population Density on Accessibility**

- Population density is positively correlated with the density of PDHFs in Riyadh, indicating that areas with higher population densities have more private dental clinics, leading to better access to dental care.

These hypotheses will guide the analysis of the spatial distribution of private dental healthcare facilities and their correlation with population density, socio-economic factors, and other variables in Riyadh. The findings will help identify underserved areas and inform policy recommendations for improving equitable access to dental care.

## **1.4 Research Objectives**

### **1. Assess the Spatial Distribution of PDHFs:**

- To evaluate the geographic distribution of private dental healthcare facilities (PDHFs) in Riyadh and identify patterns of clustering and disparities across the city's sub-municipalities.

### **2. Analyze PDHF-to-Population Ratios:**

- To calculate the PDHF-to-population ratio in each sub-municipality of Riyadh and assess whether certain areas are underserved based on the availability of dental clinics in relation to population density.

### **3. Examine Geographic Accessibility to PDHFs:**

- To determine the percentage of Riyadh's total area that falls within a 1 km, 3 km, 5 km, and greater than 5 km buffer zone around PDHFs, evaluating the accessibility of dental care services across different regions.

### **4. Evaluate the Demographics of the Dental Workforce:**

- To analyze the demographic characteristics of the dental workforce in Riyadh, including the proportion of non-Saudi dentists, gender distribution, and their specialty areas, and how these factors influence service delivery.

**5. Investigate Socio-Economic Factors Impacting Access:**

- To assess the relationship between socio-economic factors such as district income levels and the presence of PDHFs, determining whether higher-income areas have better access to dental care services.

**6. Identify Areas with Insufficient Dental Care Access:**

- To identify areas in Riyadh that are underserved by private dental clinics, based on the spatial distribution, population density, and accessibility data, and propose strategies for improving access to care in these areas.

**7. Provide Recommendations for Strategic Planning:**

- To offer evidence-based recommendations for policymakers and stakeholders in the private dental healthcare sector regarding the optimal placement of new clinics, workforce distribution, and strategies to address geographic and demographic disparities in dental care access.

## **1.5 Research Importance**

The significance of this research lies in its profound potential to reshape the landscape of dental healthcare management in Riyadh, Saudi Arabia, by providing a comprehensive understanding of the spatial distribution and accessibility of private dental clinics. The findings will have far-reaching implications for enhancing the planning and delivery of dental services throughout the city, addressing critical gaps in service provision, and fostering equitable access to

oral healthcare. By assessing the location of private dental healthcare facilities in relation to population density, this study brings to light areas where the lack of dental clinics may hinder residents' access to essential services, particularly in underrepresented or rural districts. The insights gained will inform decisions that promote an even distribution of dental clinics across Riyadh, ensuring that underserved populations are not overlooked. This, in turn, will contribute to the broader goal of fostering health equity and equal access to necessary dental care.

In a city like Riyadh, where rapid urbanization and population growth continue to exert pressure on existing healthcare infrastructure, the strategic management of dental services has never been more critical. This research plays a vital role in filling the gap in available data on the distribution of private dental healthcare facilities. The lack of such data has often led to a misalignment between the location of clinics and the areas that need them most. By providing a clear and accurate picture of how dental services are distributed across the city, this research enables policymakers to make informed, evidence-based decisions. These decisions, grounded in data, will guide future investments in dental infrastructure, ensuring that new clinics are established in areas where they can most effectively meet the needs of the growing population.

Moreover, this study delves into the socio-economic dimensions of healthcare access, addressing disparities that persist in urban healthcare systems. Through its examination of income levels and population density in relation to clinic availability, the research identifies patterns that point to the uneven distribution of resources across Riyadh. These findings will guide policymakers in formulating targeted strategies to bridge these gaps, ensuring that dental services reach populations in lower-income areas who may otherwise face significant barriers to care. By emphasizing the importance of considering socio-economic factors in healthcare planning, this

research supports efforts to reduce health inequalities, allowing all residents, regardless of their financial status, to benefit from high-quality dental care.

In addition, this study goes beyond just geographic and socio-economic disparities to examine the composition of the dental workforce in Riyadh. Analyzing the predominance of male and non-Saudi dentists in the city's private dental clinics raises important questions about workforce representation. The results could serve as a catalyst for promoting greater gender equity and national representation within the dental profession, a necessary step toward creating a healthcare environment that mirrors the diversity of the population it serves. Encouraging a more balanced and representative workforce will not only enhance the quality of care provided but will also foster a more inclusive healthcare system that is responsive to the needs of all individuals, regardless of gender or nationality.

The practical value of this research extends into the realm of strategic planning for the future of dental healthcare in Riyadh. By mapping the city's dental clinics and analyzing their proximity to population centers, the study offers critical insights into where resources should be allocated for the greatest impact. It allows health authorities and private stakeholders to identify areas that are either oversaturated with clinics or, conversely, left without sufficient facilities. This information will enable more thoughtful and deliberate resource distribution, helping to optimize service delivery and prevent unnecessary duplication of services. The ultimate goal is to create a healthcare environment where dental services are accessible to everyone, irrespective of where they live in the city.

Finally, the study's contribution to public health cannot be overstated. Given the high prevalence of dental diseases in Saudi Arabia, including dental caries and periodontitis, improving access to dental care is crucial for enhancing overall public health outcomes. This research helps

build the foundation for interventions aimed at addressing the rising burden of oral diseases. By ensuring that dental services are readily available in all areas of Riyadh, the study paves the way for improved health outcomes across the city, reducing the long-term burden of oral health problems and enhancing the quality of life for all residents.

In essence, this research is a vital step toward reimagining how dental healthcare services are distributed and accessed in Riyadh. By highlighting geographic, socio-economic, and workforce-related disparities, it offers the tools necessary to create a more equitable, efficient, and effective dental healthcare system. The findings will resonate with healthcare policymakers, urban planners, and private sector stakeholders alike, guiding them in their efforts to address the gaps in service provision and ensuring that the dental needs of all Riyadh's residents are met with care, compassion, and fairness.

## **Chapter 2: Literature Review**

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### **2.1 Literature Review**

A review of the literature on dental clinic management systems leads to studies and writings about the creation, use, and effects of these kinds of systems.

Dental clinics need to handle their patients well in order to succeed. The characteristics and capabilities of patient management modules inside dental clinic administration systems are the main subjects of this field's research. Typically, these modules contain treatment records, medical history, demographic data, and patient registration. Extensive patient profiles are critical for tailored treatment and effective workflow management, according to studies.

A crucial component of dental clinic operations, appointment scheduling affects both patient happiness and clinic productivity. The function of appointment scheduling modules in expediting the booking process, reducing wait times, and maximizing clinician schedules is examined in the literature on dental clinic management systems. Studies demonstrate how real-time appointment tracking, automated scheduling algorithms, and reminder messages can increase clinic efficiency and patient access to care.

Appointment management systems for dental clinics are essential tools in today's healthcare industry, helping to efficiently schedule and arrange patient appointments. The goal of this literature review is to present a thorough summary of the development, application, and research in this topic. The impact of appointment management systems on dental office management and patient care is evaluated, and trends, obstacles, and possibilities are identified through an exploration of the literature already in existence. Treatment planning modules in dental clinic management systems assist clinicians in developing customized treatment plans based on patients' oral health needs and preferences. Research in this area explores the integration of digital

imaging, diagnostic tools, and electronic health records to support comprehensive treatment planning workflows. Studies emphasize the importance of collaborative decision-making between clinicians and patients, facilitated by interactive treatment planning interfaces and educational resources.

Appointment management systems are essential for dental clinics to optimize clinic operations, reduce wait times, and improve patient access to care. Research emphasizes the significance of efficient appointment scheduling, accurate patient records management, and effective communication for enhancing clinic productivity and patient satisfaction.

Literature in this area explores the features and functionalities of dental clinic management systems, including online booking portals, automated reminder notifications, and real-time appointment tracking. Studies highlight the benefits of customizable scheduling algorithms, appointment prioritization, and integration with electronic health records (EHR) to streamline clinic workflows and enhance patient engagement.

The technological infrastructure of dental clinic management systems is a key focus of research, with studies examining the use of various platforms, frameworks, and technologies. Cloud-based solutions, mobile applications, and web-based interfaces are explored for their scalability, accessibility, and security features. Research also addresses challenges such as data interoperability, system integration, and cyber security to ensure the reliability and performance of appointment management systems.

User experience (UX) design principles play a crucial role in the development of dental clinic appointment management systems, impacting both clinic staff and patients. Literature in this area explores UX best practices for designing intuitive interfaces, efficient workflows, and

personalized experiences. Usability testing, user feedback, and continuous improvement processes are emphasized to enhance system usability and user satisfaction.

Effective patient engagement and communication are essential for successful dental clinic management systems. Research explores strategies for engaging patients through personalized communications, appointment reminders, and educational resources. Studies highlight the benefits of interactive patient portals, two-way messaging platforms, and telehealth integration for improving patient-provider communication and enhancing patient experiences.

Integration with other clinic management systems and workflows is crucial for the seamless operation of appointment management systems. Research examines interoperability with electronic health records (EHR) software to ensure data consistency and workflow efficiency. Studies also explore the role of dental clinic management systems in optimizing clinician schedules, resource allocation, and patient flow within dental practices.

Dental clinic management systems must prioritize security and privacy due to the sensitive nature of patient health information. The literature in this field looks at security protocols such as data encryption, audit trails, and access controls to preserve patient privacy and abide by laws like HIPAA. Emerging risks like data breaches and cyberattacks are also included in research, emphasizing the necessity of strict cybersecurity guidelines and personnel training.

An essential component of dental clinic management system effectiveness is user adoption and satisfaction. Research examines system usability, training, and support resources as well as other elements that affect user acceptance. Research indicates that in order to encourage system adoption and user happiness, stakeholder involvement, user engagement tactics, and continuous communication are crucial.

The impact of dental clinic management systems on clinical outcomes and efficiency is a focus of research, with studies examining metrics such as appointment adherence, wait times, and patient no-show rates. Research highlights the benefits of optimized scheduling algorithms, automated reminder systems, and real-time analytics for improving clinic efficiency and patient outcomes.

Future directions for dental clinic management systems research include telehealth integration, artificial intelligence, and predictive analytics. To guarantee that appointment management systems in dental practices continue to advance and improve, issues like data standardization, interoperability, and regulatory compliance need to be further addressed.

In conclusion, a comprehensive literature survey on dental clinic management systems provides valuable insights into the current state of research and practice in this field. By examining existing literature, researchers, practitioners, and policymakers can identify best practices, address challenges, and explore opportunities for innovation in dental practice management and patient care. Ultimately, the effective implementation of appointment management systems can enhance clinic efficiency, improve patient satisfaction, and contribute to better oral health outcomes.

Literature review refers on interview, book, and Internet to get some information about this project to give a clearance perspective in developing for this project. This topic will be discussed about overview of the manual system, study on the development tools and database management system. In computer science, information system is all about information technology and mediates the two opposing worlds of human activity (Steve Elky, 2006). Current system of the dental clinic also has the system that can handle the process management as a computerized. But, there are a few problem during using the system and that cause they used the manually system. So, this

literature review has been covered about the process of the manual system that cause the current system is difficult to use.

Management system actually has been used long time ago. Every organization needs a system that can manage their data and process. Normally they used a conventional method to manage and store their data. Management system is management documented and tested step-by-step method aimed at smooth functioning through standard practices.

In every company, keeping record are very important. For the clinic, it is very important to keep the patient record for any reference. There is some method in keeping the record such as using the manual method or the computerized method. The computerized system is better than manual system in keeping record (Egwunyenga, 2009) of the patients. Hence, using the computerized system has so many advantages than the manual system. One of the advantages using a computerized system is that it is not only easy, but it also saves the time to search the patient record. If they use the manual keeping 6 record, they have a hard time to find for it. The computerized system will give the opportunity for the companies to do work more effective and efficiently if the company use it (Dalcı & Tanış).

**1. Crisan, E. L., Covaliu, B. F., & Chis, D. M. (2021). A systematic literature review of quality management initiatives in dental clinics. *International Journal of Environmental Research and Public Health*.**

This systematic literature review examines quality management initiatives in dental clinics, focusing on their implementation, challenges, and impact on healthcare delivery. The study synthesizes research from diverse sources to identify best practices and trends in quality improvement tailored to dental healthcare settings. Key themes include enhancing patient

satisfaction, ensuring adherence to clinical guidelines, improving operational efficiency, and integrating modern technologies.

The review highlights the importance of continuous staff training, effective leadership, and a patient-centered approach to achieving high standards of care. Findings reveal that while quality management initiatives have significantly improved clinical outcomes and operational workflows, challenges such as resistance to change, resource limitations, and inconsistent implementation remain prevalent.

The study concludes by proposing strategies to address these challenges, including adopting standardized frameworks, leveraging digital tools, and fostering a culture of quality within dental clinics. Future research directions are recommended to explore the long-term impacts of these initiatives and to develop innovative solutions for sustainable quality improvement in dental healthcare.

## **2. Goh, W. P., Tao, X., Zhang, J., & Yong, J. (2016). Decision support systems for adoption in dental clinics: a survey. *Knowledge-Based Systems*.**

This survey investigates the adoption of Decision Support Systems (DSS) in dental clinics, exploring their potential to enhance clinical decision-making, patient outcomes, and overall operational efficiency. The study reviews the current state of DSS technologies in dental practices, analyzing their applications across diagnostic support, treatment planning, patient management, and integration with electronic health records (EHR).

The survey identifies the benefits of DSS, including improved decision accuracy, faster treatment planning, and streamlined clinic operations. However, challenges such as high implementation costs, integration complexities with existing systems, and resistance to technology adoption are

also highlighted. The findings suggest that while DSS has the potential to significantly improve dental care, overcoming these barriers is crucial for widespread adoption.

The paper concludes by offering recommendations for facilitating the adoption of DSS in dental clinics, such as fostering greater collaboration between dental professionals and IT developers, providing training, and addressing the cost-benefit analysis of implementing such systems. Future research is encouraged to explore the scalability of DSS across different clinic sizes and specialties, as well as their impact on long-term patient care.

**3. Dhanore, P., Shaik, A., & Ramtekkar, P. (2016). Dental Clinic Management System-A New Approach. *International Journal of Science, Engineering and Computer Technology*.**

This study introduces a new approach to designing and implementing a Dental Clinic Management System (DCMS) aimed at addressing the limitations of traditional management practices in dental clinics. The proposed system integrates key modules such as patient registration, appointment scheduling, electronic health records, billing, inventory management, and reporting into a cohesive, user-friendly digital platform.

The development process follows a modular design approach to ensure flexibility, scalability, and ease of use. The system's architecture supports seamless data flow and secure storage, enhancing operational efficiency and reducing administrative burdens. Preliminary evaluations highlight the DCMS's ability to minimize manual errors, improve workflow management, and enhance patient satisfaction through improved service delivery.

The paper also discusses challenges encountered during development, such as ensuring data privacy and adapting to diverse clinic requirements. Recommendations for future improvements include incorporating advanced analytics, telemedicine capabilities, and mobile integration. This

study underscores the transformative potential of digital solutions in modernizing dental clinic operations and fostering higher standards of patient care.

**4. Ho, S. B., Chew, E. Y., & Tan, C. H. (2024). Streamlining Dental Clinic Management for Effective Digitisation Productivity and Usability. *Journal of Informatics and Web Engineering*.**

This paper explores the development of the Temangan Dental Clinic Management System (TDCMS), an innovative digital solution designed to address operational inefficiencies and enhance patient care in dental clinics. The system integrates key functionalities, including patient registration, appointment scheduling, electronic medical records, billing, and inventory management, within a user-friendly interface. The authors adopted a structured software development lifecycle (SDLC) to ensure the system's robustness, scalability, and usability.

Preliminary testing of the TDCMS demonstrated its effectiveness in streamlining administrative tasks, reducing manual errors, and improving service delivery. By automating routine processes, the system allows dental staff to focus more on patient care, resulting in enhanced clinic productivity and customer satisfaction. This study also identifies potential challenges, such as ensuring data security and staff training, and proposes strategies for overcoming them.

The paper concludes by discussing the system's broader implications for digital transformation in healthcare, including its scalability for adoption in larger clinic networks and future integration with advanced technologies like AI and telemedicine.

**5. Zawawi, N. I. A., & IBRAHIM, T. D. R. (2023). Development of Temangan Dental Clinic Management System. *Applied Information Technology And Computer Science*.**

This paper presents the development of the Temangan Dental Clinic Management System (TDCMS), a comprehensive digital solution aimed at improving the operational efficiency and patient care in dental clinics. The system integrates essential modules such as patient registration, appointment scheduling, treatment management, billing, and inventory control, all within a unified platform. The authors describe the system's architecture, design methodology, and the technologies employed to ensure its scalability, user-friendliness, and data security.

Through an iterative development process, the system was tailored to meet the specific needs of the Temangan Dental Clinic, with user feedback incorporated at each stage to refine the platform's functionality. The study highlights the successful implementation of the system, which resulted in improved workflow, reduced administrative workload, and enhanced communication between dental staff and patients. Additionally, the paper discusses challenges encountered during development, such as integrating legacy systems and ensuring compliance with healthcare regulations.

The study concludes by proposing future enhancements, including the integration of advanced features like telemedicine capabilities, patient feedback mechanisms, and artificial intelligence to further optimize clinic operations and patient satisfaction. The TDCMS serves as a model for other dental clinics seeking to modernize their management processes through digital transformation.

**6. Sihombing, D. J. C. (2024). Developing Customer Relationship Management Application for Dental Clinic Using Agile Approach to Enhance Efficiency and Customer Satisfaction. *Jurnal Ekonomi*, 13(01), 2558-2569.**

This research focuses on the design and implementation of a Customer Relationship Management (CRM) application tailored for dental clinics, leveraging the Agile development approach to

optimize both operational efficiency and customer satisfaction. The application incorporates features such as automated appointment reminders, real-time scheduling, secure patient record management, treatment tracking, and personalized care recommendations. Using the Agile methodology, the development process emphasized iterative improvements, stakeholder collaboration, and rapid prototyping to address the unique requirements of dental clinic operations. The study evaluates the application's performance through usability testing and feedback from clinic staff and patients. Results demonstrate significant benefits, including streamlined administrative workflows, enhanced communication between staff and patients, and increased patient retention rates. By integrating customer-centric functionalities, the CRM system fosters a more personalized and efficient patient experience.

The paper also identifies challenges encountered during development, such as data security concerns and integration with existing clinic management systems. Future recommendations include the incorporation of advanced analytics, AI-driven patient insights, and broader scalability to accommodate multi-clinic networks. The study concludes that Agile-driven CRM development offers a flexible and effective pathway for advancing technology adoption in the dental healthcare sector.

7. **Saaïd Al Shehadat, El-Kishawi, M., Asma AlMudalal, Asma AlSaqr, Nassar, A., Zihlif, L., Mahmoud, Y., Venkateshbabu Nagendrababu, & Thilla Sekar Vinothkumar. (2022). An Audit of the Technical Quality and Iatrogenic Errors of Root Canal Treatment by Undergraduate Dental Students at the University of Sharjah. *European Journal of Dentistry*.**

This study aims to audit the technical quality and iatrogenic errors associated with root canal treatments performed by undergraduate dental students at the University of Sharjah. A retrospective analysis was conducted on a sample of root canal treatments completed by final-year students, evaluating both the technical proficiency of the procedures and the occurrence of iatrogenic errors. The audit focused on key aspects such as canal preparation, obturation quality, and the presence of periapical lesions, as well as the incidence of procedural errors, including over-instrumentation, under-obturation, and perforations.

The findings revealed a significant variation in the quality of root canal treatments, with several cases demonstrating suboptimal technical outcomes and a noticeable presence of iatrogenic errors. However, certain factors, such as the level of student experience and supervision, were found to influence the outcomes positively. The study emphasizes the importance of structured training, continuous assessment, and the use of advanced technologies to improve the technical proficiency of dental students.

This paper concludes by offering recommendations to reduce iatrogenic errors and enhance the overall quality of root canal treatments, including more focused educational interventions, greater emphasis on hands-on experience, and improved diagnostic tools. Further research is needed to explore the long-term effects of these interventions on student performance and patient outcomes.

- 8. E. V. Shott, I. O. Pohodenko-Chudakova, Morphological Features of the Structure of the Root Canals of Premolars and Molars of the Upper Jaw on the Basis of Cone-Beam Computed Tomography, Ukraïns'kij žurnal medicini, bìologïi ta sportu, 10.26693/jmbs06.05.322, 6, 5, (322-328), (2021).**

This study investigates the morphological features of the root canal structures of premolars and molars in the upper jaw, using Cone-Beam Computed Tomography (CBCT) for detailed analysis. The aim was to examine the anatomical variations and complexity of root canal systems in these teeth, which are critical for successful endodontic treatments. The research involved the analysis of CBCT scans from a sample of patients, focusing on key parameters such as the number of roots, the number of canals, the presence of additional or unusual canal configurations, and the overall canal morphology.

The results revealed significant variations in the root canal systems of premolars and molars, with a variety of anatomical features that could influence treatment planning and outcomes. In particular, the study identified a high incidence of complex root canal systems in molars, including the presence of extra canals and variations in canal curvature. Premolars also demonstrated considerable diversity in canal configurations, with implications for the approach to root canal treatment.

The paper concludes by highlighting the importance of using advanced imaging techniques like CBCT to better understand tooth morphology, improve the accuracy of root canal treatments, and minimize the risk of procedural complications. The study underscores the need for personalized treatment planning based on detailed anatomical knowledge to ensure successful endodontic outcomes.

- 9. Iosif, L., Bogdan Dimitriu, Nițoi, D. F., & Oana Amza. (2023). Endodontic Dentistry: Analysis of Dentinal Stress and Strain Development during Shaping of Curved Root Canals. *Healthcare*.**

This study examines the dentinal stress and strain development during the shaping of curved root canals in endodontic dentistry, focusing on how different instrumentation techniques affect the structural integrity of the tooth. The research employs computational models and experimental analysis to assess how various shaping methods influence stress distribution in the dentin during root canal preparation. The study highlights the challenges associated with shaping curved canals, which are particularly susceptible to iatrogenic errors, including ledging and fracture, due to excessive stresses placed on the canal walls.

The results demonstrate that the type of instrument used and the specific technique employed have a profound impact on dentinal stress. Techniques using rotary files, particularly those with controlled memory or specific design features, were found to produce more favorable stress distributions, reducing the likelihood of dentinal damage. In contrast, hand instruments and rotary systems that exert excessive torque were associated with higher stress concentrations, which could compromise the tooth's structural integrity and increase the risk of procedural errors.

The paper underscores the importance of choosing appropriate instruments and techniques to minimize stress and preserve dentin during endodontic procedures. It suggests that further advancements in shaping systems could lead to improved treatment outcomes, enhancing both the safety and efficacy of root canal therapy. The findings are valuable for endodontic practitioners, offering insights into optimizing treatment strategies to protect tooth health and ensure the long-term success of root canal treatments.

### **Chapter 3: Research Methodology**

## **Chapter 3: Research Methodology**

### **3.1 Research Methodology**

#### **3.1.1 Data Collection**

This study was conducted in August 2024. The study proposal was exempt from Institutional Review Board (IRB) review as it did not involve human subjects or related data, and all data were anonymized. Official approval was granted by the research office at King Abdullah International Medical Research Center (#RSS23R/015). Riyadh, the capital and most populous city in Saudi Arabia, spans 1,973 km<sup>2</sup> and is divided into 16 sub-municipalities [12]. The study analyzed the spatial distribution of private dental healthcare facilities (PDHFs) within these sub-municipalities and calculated the number of PDHFs per capita in each district.

All specialized private dental clinics registered with the Ministry of Health (MOH) Health Affairs system were included in the study. Clinics within hospitals, however, were excluded. Data collection involved visiting dental centers, where representatives completed a standardized questionnaire. Participation was voluntary, and clinics that declined were documented and excluded from further analysis. Collected data included the number of practicing dentists, their gender, specialty, classification, and nationality, along with the clinic's location, year of establishment, and contact information. Geographic locations were recorded using the shared location tool in Google Maps (California, USA).

#### **3.1.2 Location of PDHFs**

The study included operational PDHFs across Riyadh, such as dental clinics, dental and dermatology polyclinics, and dental departments in hospitals. Excluded were dental schools, mobile dental clinics, and government healthcare facilities. A total of 632 PDHFs were analyzed,

excluding 98 non-operational facilities or those with expired licenses. Information about each PDHF's number, location, and operability was obtained from the MOH database.

### **3.1.3 Geographic Integration**

Geographic data were referenced using Ain el Abd/UTM zone 38N coordinates. Precise locations of sub-municipalities and districts were exported from the Riyadh municipality map [12] to Quantum Geographic Information System (QGIS) software (version 3.32.1, Essen, Germany). This software facilitated the visualization, analysis, and interpretation of spatial data.

### **3.1.4 Mapping**

Fifteen residential sub-municipalities were analyzed. The geographic locations of PDHFs were converted to longitude and latitude coordinates using Google Earth (version 10.52.0.0, Google, Sunnyvale, CA, USA) [13]. These locations were plotted on QGIS and treated as central points for analysis. Four buffer zones—1 km, 3 km, 5 km, and >5 km—were created around each central point to assess the coverage area of each PDHF. Coverage was measured in square kilometers (km<sup>2</sup>).

### **3.1.5 Population Statistics**

Population statistics and average monthly individual income per district were obtained from the Zadd.910ths website, a governmental resource providing interactive and updated demographic data [14].

### **3.1.6 Statistical Analysis**

District and sub-municipality areas were calculated in square kilometers (km<sup>2</sup>) using QGIS. Descriptive statistics were analyzed using Microsoft Excel (version 16.0, Microsoft, Redmond, WA, USA). The strength of associations between continuous variables was evaluated using Pearson's correlation test. RStudio software (version 4.1.3, Posit Software, PBC, Boston, MA, USA) was employed to create the Lorenz curve, providing a visual representation of data distribution.

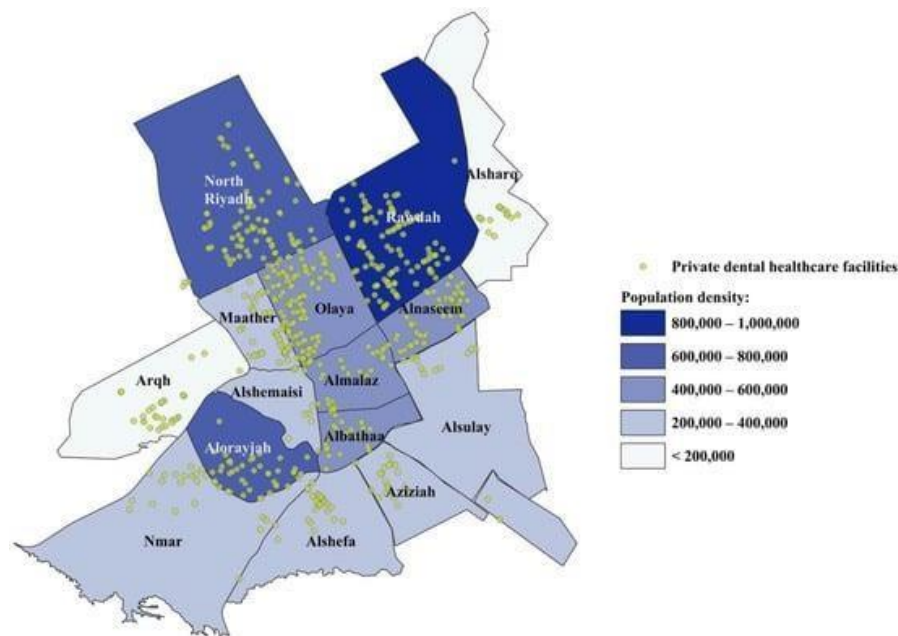
This methodology enabled a comprehensive evaluation of the spatial distribution and accessibility of private dental healthcare facilities in Riyadh, providing valuable insights for healthcare planning and policy development.

## **Chapter 4: Results**

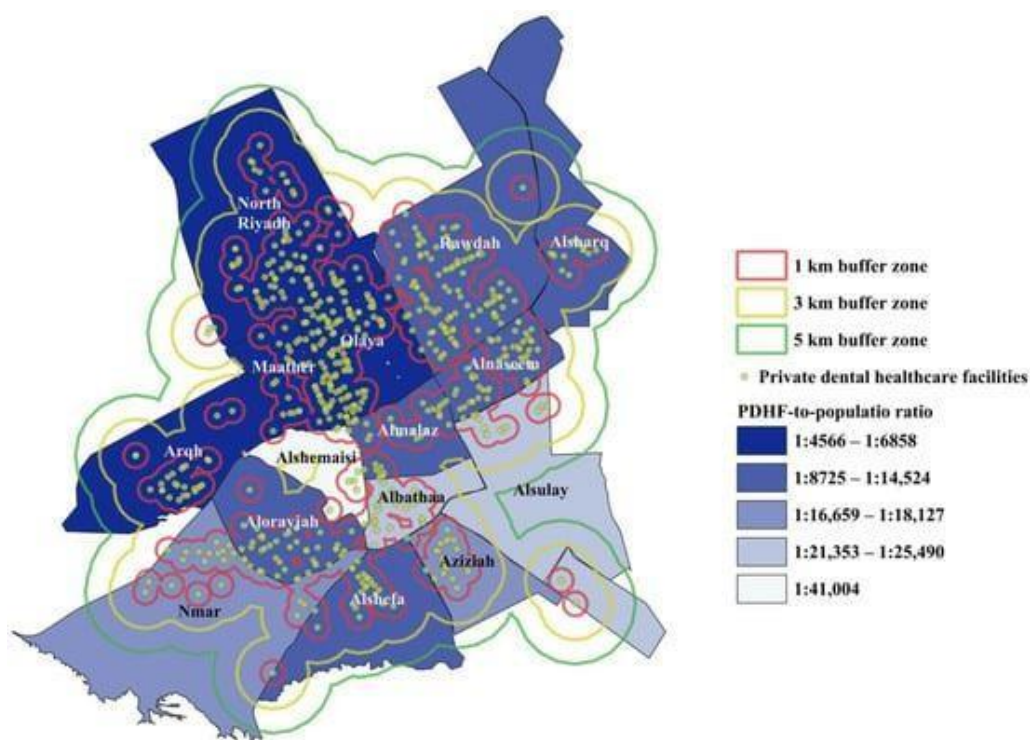
## Chapter 4: Results

### 4.1 Results

Riyadh city consists of 16 sub-municipalities with a population of 6,500,000 residents [14]. More than a third of these residents (35.4%, 2,225,665) reside mainly in three sub-municipalities: Rawdah (15.4%, 968,565), Alorayjah (10.4%, 653,600), and North Riyadh (9.6%, 603,500) (Table 1). A total of 632 PDHFs were geocoded by QGIS. Graphical data representation was used to show the distribution of PDHFs in Riyadh city. Figure 1 shows the population densities and private dental healthcare facilities' spatial distribution in Riyadh city. Coverage areas of the dental facilities were mapped out and delineated by four buffer zones: 1 km, 3 km, 5 km, and >5 km, with each PDHF being a centroid (Figure 2).



**Figure 1.** Population density and private dental healthcare facilities' spatial distribution in Riyadh city.



**Figure 2.** Coverage of private dental healthcare facilities and population ratios per sub-municipality in Riyadh city.

**Table 1.** Private dental healthcare facilities-to-population ratios per sub-municipality in Riyadh city.

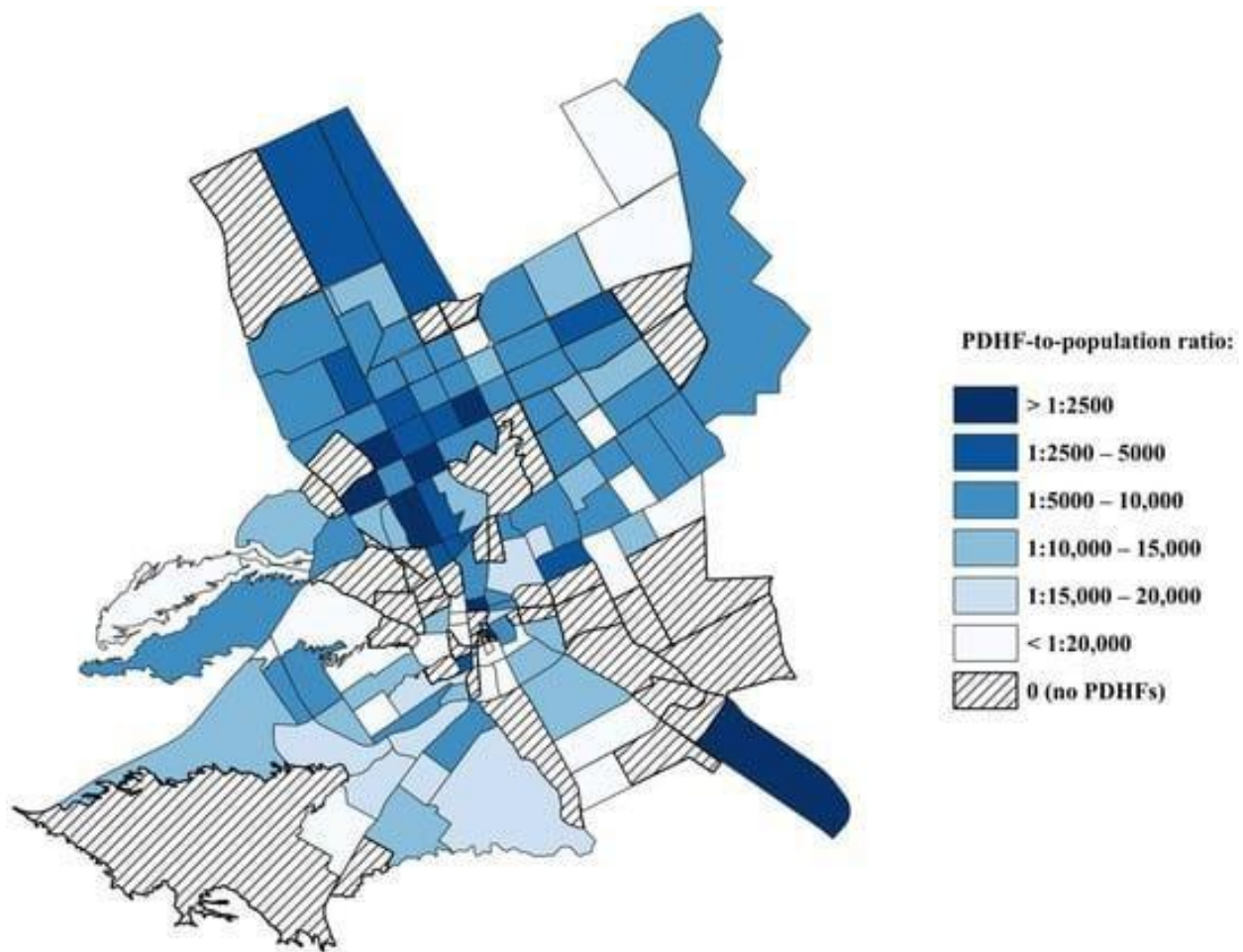
| Sub-Municipality | PDHF<br>(No.) | Population<br>(No.) | PDHF-to-Population Ratio |
|------------------|---------------|---------------------|--------------------------|
| Olaya            | 106           | 483,963             | 1:4566                   |
| Maathir          | 42            | 202,782             | 1:4828                   |
| Arqah            | 29            | 174,305             | 1:6011                   |
| North Riyadh     | 88            | 603,500             | 1:6858                   |
| Rawdah           | 111           | 968,565             | 1:8725                   |
| Alnaseem         | 52            | 530,800             | 1:10,208                 |
| Almalaz          | 37            | 410,776             | 1:11,102                 |

|                   |     |           |          |
|-------------------|-----|-----------|----------|
| <b>Alshefa</b>    | 24  | 286,173   | 1:11,924 |
| <b>Alsharq</b>    | 15  | 184,328   | 1:12,289 |
| <b>Alorayjah</b>  | 45  | 653,600   | 1:14,524 |
| <b>Nmar</b>       | 22  | 366,500   | 1:16,659 |
| <b>Aziziah</b>    | 19  | 344,415   | 1:18,127 |
| <b>Albathaa</b>   | 23  | 491,119   | 1:21,353 |
| <b>Alsulay</b>    | 12  | 305,883   | 1:25,490 |
| <b>Alshemaisi</b> | 7   | 287,027   | 1:41,004 |
| <b>Total</b>      | 632 | 6,293,736 | 1:9958   |

Almost half of the PDHFs (48.3%, 305/632) were clustered in only three sub-municipalities: Rawdah (17.6%, 111/632), Olaya (16.8%, 106/632), and North Riyadh (13.9%, 88/632); however, these three sub-municipalities have about one-third of total Riyadh population (32.6%, 2,056,028/6,500,000). Furthermore, although Olaya had the second-highest number of PDHFs, it was not one of the most populated sub-municipalities, ranked fifth regarding total population. North Riyadh and Alorayjah had similar total populations; however, the number of PDHFs in North Riyadh (88) was almost twice of that located in Alorayjah (45) (Table 1). On the other hand, Alshemaisi (1.1%, 7/632), Alsulay (1.9%, 12/632), and Alsharq (2.4%, 15/632) sub-municipalities had the lowest numbers of PDHFs. Looking at the districts' level, Thrh Labn (3.79%, 24/632), Olaya (3.16%, 20/632), and Alnaseem Algharbi (3%, 19/632) districts had the highest numbers of PDHFs while there were 42 districts that did not have any PDHFs, mostly located in Albathaa (10 districts), Alshemaisi (8 districts), and Alsulay (5 districts) sub-municipalities (Table 1).

The overall private dental healthcare facility-to-population ratio in Riyadh city was one PDHF per 9958 residents. Looking at the ratios of each sub-municipality, Olaya and Maather sub-municipalities had the largest PDHF-to-population ratios: (1:4566) and (1:4828), respectively. This

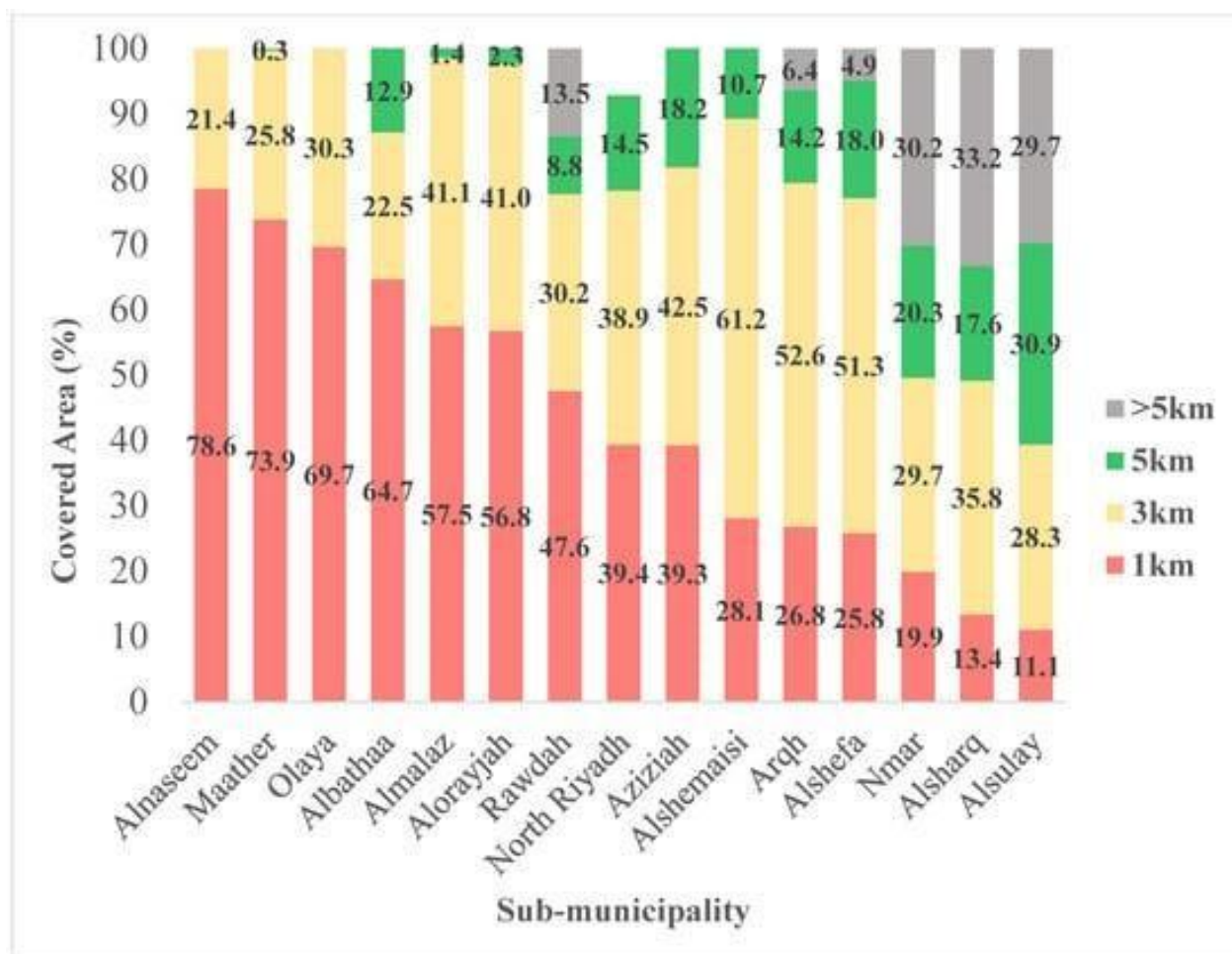
may indicate the oversaturation of PDHFs in these two sub-municipalities as Olaya was not the most populated sub-municipality and Maather was the third least populated. On the contrary, Alshemaisi had the smallest PDHF-to-population ratio (1:41,004), followed by Alsulay (1:25,490) and Albathaa (1:21,353) (Table 1, Figure 2 and Figure 3).



**Figure 3.** Private dental healthcare facilities-to-population ratios per district in Riyadh city.

Looking at the covered areas in square kilometers (km<sup>2</sup>) using the four buffer zones around each PDHF, the majority of (86.7%) of Riyadh city total area was located within 5 km of a PDHF, and almost three-quarters (72.5%) of the total area was within 3 km while only a little above one third (36.3%) was within 1 km buffer zones. The sub-municipalities that had the highest coverage

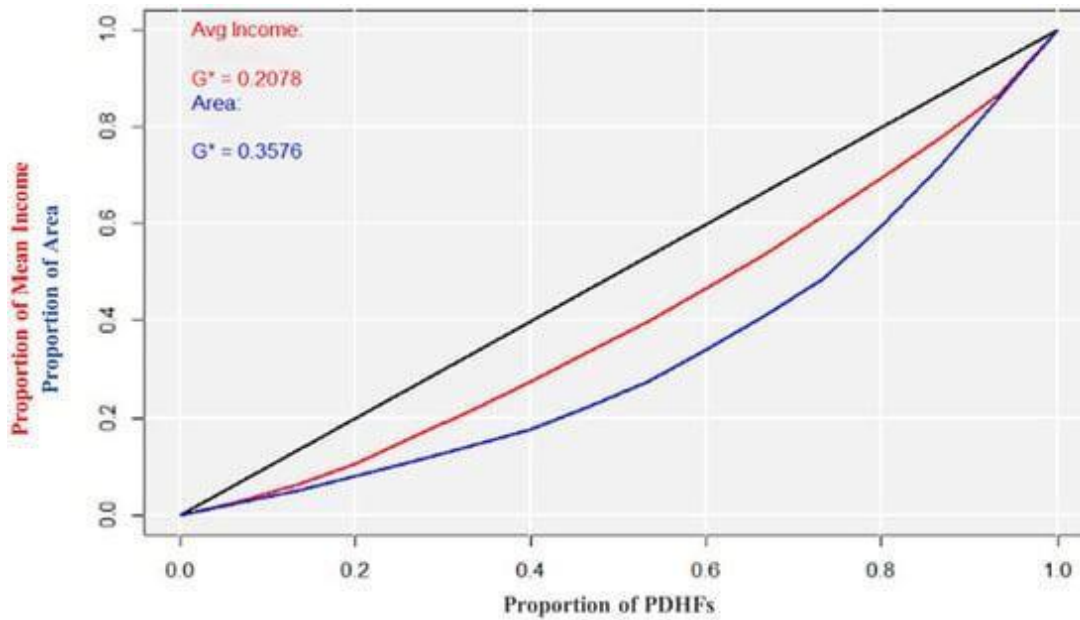
within 1 km buffer zones were Alnaseem (78.6%), Maather (73.9%), and Olaya (69.7%). All the districts of the Alnaseem sub-municipality had at least half (50%) of the area located within 1 km from a PDHF, with the Alrawabi district having complete (100%) coverage within 1 km (Figure 4). Moreover, the districts with the highest coverage in the Maather sub-municipality were Olaya and Almuhamadeyah, with complete (100%) coverage within 1 km buffer zones, while other districts had at least 50% coverage within 1 km buffer zones except for the King Saud University area (42.6%). Half of the districts located in the Olaya sub-municipality (7/14) were completely (100%) covered within 1 km buffer zones: Altaawuon, Olaya, Almaseef, Alworood, King Fahad, Alnuzhah, and Almorouj districts, while the remaining districts had at least 60% coverage within 1 km buffer zones except for the King Abdulaziz district (8.1%) that had the least coverage, followed by the King Abdullah district (44.9%). On the other hand, some sub-municipalities were underserved in Riyadh city. The sub-municipalities that had the least coverage within the 1 km buffer zones were Alsulay (11.1%), Alsharq (13.4%), and Nmar (19.9%). Moreover, these three sub-municipalities had the largest percentages of areas located out of 5 km buffer zones: Alsharq (33.2%), Nmar (30.2%), and Alsulay (29.7%) (Figure 4).



**Figure 4.** Comparison between the percentages of areas covered within four buffer zones for each sub-municipality in Riyadh city.

Pearson's test showed an overall weak positive correlation between the number of PDHFs and total area of each sub-municipality ( $r = 0.29$ ). However, there was a stronger overall positive correlation between the number of PDHFs and the total population in each sub-municipality ( $r = 0.74$ ), indicating an increase in the number of PDHFs as the population increases; however, this does not necessarily mean the increase was even or followed a consistent proportion. Furthermore, the correlation between the mean individual income and number of PDHFs per district was negative in nine sub-municipalities: Alnaseem ( $r = -0.90$ ), Alsharq ( $r = -0.72$ ), Arqh ( $r = -0.47$ ),

North Riyadh ( $r = -0.44$ ), Alshemaisi ( $r = -0.44$ ), Olaya ( $r = -0.25$ ), Nmar ( $r = -0.21$ ), Maather ( $r = -0.16$ ), and Rawdah ( $r = -0.05$ ), while it was positive in the other six sub-municipalities: Aziziah ( $r = 0.69$ ), Alsulay ( $r = 0.51$ ), Albathaa ( $r = 0.38$ ), Alorayjah ( $r = 0.23$ ), Almalaz ( $r = 0.23$ ), and Alshefa ( $r = 0.22$ ). The Lorenz curve and Gini coefficient were determined to evaluate the distribution of PDHFs. The density of PDHFs corresponding to the area in square kilometers (km<sup>2</sup>) was estimated. The Lorenz curve was plotted with the cumulative proportion of PDHFs on the x-axis and proportions of mean income and area on the y-axis (Figure 5). The curve in blue color represents the distribution of PDHFs in Riyadh city corresponding to the area with a Gini coefficient of 0.357, indicating a moderate level of disparity in the distribution of PDHFs corresponding to the area. The curve in red color represents the distribution of PDHFs corresponding to the mean income with a Gini coefficient of 0.207, indicating almost equality in the distribution of PDHFs in Riyadh city corresponding to the mean income.



**Figure 5.** Lorenz curve and Gini coefficients: Riyadh city distribution of private dental healthcare facilities corresponding to mean individual income and area. PDHFs: private dental healthcare facilities. Avg: average (mean). G\*: standardized Gini coefficient.

The MOH list provided has a total of 236 dental clinics registered and they were all visited. Out of 236 clinics, 68.6% (n = 162) accepted to be enrolled while 31.4% (n = 74) refused to participate. It was found that the total number of dentists were 877. The majority of dentists were males (n = 561, 63.97%) compared to female dentists (n = 316, 36.03%). With respect to their nationality, the majority of dentists were non-Saudis (n = 760, 86.66%). The Syrian dentists (n = 353, 40.25%) were the highest among all other nationalities, followed by Egyptians dentists (n = 150, 17.10%). Dentists who are being identified to be Saudi were 13.34% (n = 117). The full list of all nationalities of dentists analyzed were shown in Table 1. As for dental specialty, the general practitioners were the highest dentists' group (70.5%; n = 618) compared to specialists and consultants (29.5% n = 259). Furthermore, among specialists/consultants, orthodontists had the highest number (42.9%; n = 111), and were mostly females (28.5%; n = 32). The distribution of other specialties is shown in Table 2.

The year of establishment of clinics visited were categorized accordingly. As shown in Table 3, the number of clinics between the periods from 1984 to 1990 and 2011 to 2016, were 10, and 59, respectively. The location of all private dental clinics was also analyzed. It was found that among the 236 dental clinics registered, Olaya and Rawdha had the highest number of clinics: 49 and 45, respectively (Table 4).

**Table 2.** *Nationality of practicing dentists in private dental clinics.*

| <b>Nationality</b>       | <b>Number</b> |
|--------------------------|---------------|
| Syria                    | 353           |
| Egypt                    | 150           |
| Saudi Arabia             | 117           |
| Philippine               | 78            |
| Palestine                | 40            |
| Sudan                    | 33            |
| Yemen                    | 30            |
| Jordan                   | 29            |
| Lebanese                 | 15            |
| India                    | 12            |
| United States of America | 5             |
| Canada                   | 3             |
| Venezuela                | 3             |
| Tunisia                  | 2             |
| Colombia                 | 2             |
| South Africa             | 1             |
| Mexico                   | 1             |
| Eritrea                  | 1             |
| Chile                    | 1             |
| Azerbaijan               | 1             |
| Total                    | 877           |

**Table 3.** *Classification according to dental specialty of practicing dentists in private dental clinics.*

| <b>Specialty</b> | <b>Number</b> |
|------------------|---------------|
| General dentist  | 618           |

|                          |     |
|--------------------------|-----|
| Orthodontist             | 111 |
| Prosthodontist           | 55  |
| Oral surgeon             | 27  |
| Endodontist              | 26  |
| Pedodontist              | 15  |
| Periodontist             | 13  |
| Restorative dentist      | 10  |
| Advanced general dentist | 2   |
| Total                    | 877 |

**Table 4.** Establishment year of private dental clinics in Riyadh city.

| Years of establishment | Number of clinics |
|------------------------|-------------------|
| From 1991 to 1998      | 10                |
| From 1999 to 2003      | 14                |
| From 2004 to 2008      | 18                |
| From 2009 to 2013      | 27                |
| From 2014 to 2018      | 34                |
| From 2019 to 2024      | 59                |
| Total                  | 162               |

**Table 5.** Location distribution of private dental clinics in Riyadh city according to municipality

| Municipality | Number |
|--------------|--------|
| Olaya        | 49     |
| Rawdah       | 45     |
| Naseem       | 27     |
| North        | 26     |
| Uraiya       | 18     |
| Shifa        | 14     |
| Mathar       | 12     |

|          |     |
|----------|-----|
| Malaz    | 11  |
| Namar    | 9   |
| Aziziyah | 8   |
| Iraqah   | 6   |
| Batha    | 4   |
| Sulai    | 4   |
| Shomaisi | 2   |
| Omarya   | 1   |
| Total    | 336 |

## **Chapter 5: Discussion and Conclusions**

## **Chapter 5: Discussion and Conclusions**

### **5.1 Discussion**

Healthcare in Saudi Arabia is one of the main focus areas of vision 2030. One of its initiatives to be accomplished is to expand privatization of health services and increase the efficient utilization of available resources and the use of technology and digital information (Vision, 2020). The current governmental data about dental private clinics in Riyadh city lacks basic information, clinician's gender, nationality, specialty, and location of dental centers. Therefore, the current study aimed to develop a database and analyze clinicians' workforce of private dental clinics in Riyadh city.

Accessibility to dental healthcare is a key factor affecting the utilization of dental services, in addition to financial reasons, attitudes toward dental care [15], and the availability of high-quality dental services [16,17]. Enhancing access to healthcare is one of the goals of the Saudi Vision 2030, and the private healthcare sector is an essential partner to help in achieving this important goal. The dental healthcare private sector in Riyadh city has been growing rapidly over the past few years. However, there is a lack of information regarding the spatial distribution of PDHFs and a need for a more comprehensive analysis and details about the saturation of PDHFs. The distribution of PDHFs in Riyadh city is an important topic as it sheds light on the accessibility to dental healthcare services. Therefore, this study was conducted.

As of August 2024, there were 632 operating PDHFs registered in MOH. A Geographical Information System (GIS)-based approach was utilized in this study. The project started with analyzing the map of Riyadh city, its sub-municipalities, and districts. According to the governmental website of Riyadh Municipality Portal, Riyadh city is divided into 16 sub-municipalities. Fifteen sub-municipalities were included and analyzed in this study [12]. Alhayer

sub-municipality was excluded due to the lack of population statistics and the absence of registered PDHFs, which could be explained by the fact that it included mainly non-residential areas.

Each PDHF was treated as a central point and buffer zones were created around each one. Four levels of buffer zones were selected for this study with 1 km being the smallest as shown in Figure 2. One kilometer represents the shortest straight-line distance (radius) around each PDHF and may not represent the actual route, which would likely be longer driving a car considering road obstacles and traffic. In addition, Riyadh is a metropolitan area and the capital city with significant traffic congestion (traffic congestion index = 21.98) [18]. There is no universally approved distance for access to care. Riyadh city is considered the most congested city in Saudi Arabia with a peak vehicle speed of 46.7 km/h during morning and afternoon periods [19]. Thus, the levels of buffer zones were set at 1 km, 3 km, 5 km, taking into consideration the time to travel to the nearest dental healthcare facility in each district and the relative saturation of PDHFs in Riyadh. Several sub-municipalities in Riyadh city showed multiple shared patterns of PDHFs distribution and PDHF-to-population ratios. For instance, Olaya, Maather, North Riyadh, and Rawdah sub-municipalities had the largest PDHF-to-population ratios at 1:4566, 1:4828, 1:6858, 1:8726, respectively. The percentages of the areas covered within 1 km buffer zones were Maather (73.9%), Olaya (69.7%), Rawdah (47.6%), and North Riyadh (39.4%). A total of 347 PDHFs (54.9% of included PDHFs) were located within these four sub-municipalities. This may indicate significant clustering of PDHFs in these sub-municipalities. On the other hand, less than 50% of the areas of Alshefa, Alsharq, Nmar, Aziziah, and Alsulay sub-municipalities were within 1 km from 92 facilities (Figure 4). The PDHF-to-population ratios in these sub-municipalities were 1:11,924, 1:12,289, 1:16,659, 1:18,127, and 1:25,490.25, respectively. This may demonstrate an uneven distribution of PDHFs with an inadequate number of facilities to serve these highly

populated sub-municipalities. In Alnaseem, Almalaz, Alorayjah, and Albathaa sub-municipalities, there were 157 PDHFs distributed over 51 districts, with more than 50% of the area of these sub-municipalities being within 1 km of PDHFs (Figure 4). However, the PDHF-to-population ratios in these sub-municipalities were relatively low, precisely equal to 1:10,208, 1:11,102, 1:14,524, and 1:21,353, respectively, indicating the number of PDHFs might not be sufficient to serve the entire population in these sub-municipalities although the spatial distribution of PDHFs seemed relatively even (Figure 2). A more unique pattern of distribution was noticed in two sub-municipalities: Arqh and Alshemaisi. Arqh sub-municipality had the third largest PDHF-to-population ratio (1:6011); however, only 26.8% of the total areas were within 1 km of 29 PDHFs. This may demonstrate that although the number of PDHFs seemed quite adequate to serve the population, the facilities were not evenly distributed across these two sub-municipalities. In contrast, Alshemaisi sub-municipality had only seven PDHFs with the lowest PDHF-to-population ratio (1:41,004), and only 28.1% of the area was within a 1 km range of PDHFs, indicating a lack of private facilities in this sub-municipality. This could be explained by the presence of a large governmental healthcare facility, King Saud Medical City. In general, the findings of the present study showed a tendency of significant clustering of PDHFs in northern, central, and northeastern parts of Riyadh city.

Previous studies were conducted to analyze the distribution of dental services in KSA. Shubayr and his co-workers [10] reported that there was an uneven distribution of dental services in the Jazan region, although there was a positive correlation between the distribution of dental clinics and population density across Jazan region, which is in agreement with the findings of this study. The overall dental clinics-to-population ratio reported in the Jazan region was one PDHF per 6279 residents, which is more favorable than the ratio found in the present study (1:9958). This

could be explained by the fact that Riyadh city is more densely populated, being the capital city, and that Shubayr and his co-workers included both public and private dental clinics in their analysis. On the contrary, a study conducted in 2020 reported a ratio of one dental clinic per 13,647 residents in Al Madina city, which is much lower although both public and private dental clinics were included [8]. A study conducted in 2016 reported that the overall dental clinic-to-population ratio in Malaysia was 1:9000; 1:38,000 for public dental clinics and 1:13,000 for private facilities; however, the clinics were unevenly distributed across the country [20].

Alsalleeh and his co-workers [11] investigated the number of private dental clinics and the number of dentists in Riyadh city. They reported that private dental clinics were not evenly distributed in Riyadh city, which is in agreement with the present study. However, they determined the number of clinics in each sub-municipality without mapping out the exact distribution. Mapping the clinics in GIS should give further details regarding the facilities' distribution, saturation, and accessibility in each district. The number of dental clinics included in their study was obtained from the Ministry of Health (MOH)—a total of 236 registered dental clinics. Comparing the number of dental clinics registered in 2016 to the number collected in this study shows that the number of dental healthcare facilities has tripled, signifying the rapid expansion of this sector over the past few years. Their results showed that Olaya and Rawdha had the highest number of dental clinics, 49 and 45, respectively, which aligns with the results found in the present study, 106 and 111, respectively. Alsalleeh and his co-workers collected information about the number of dentists and available specialties; however, almost one third of (31.4%, 74/236) the dental clinics refused to be enrolled.

The Lorenz curve and Gini coefficient are essential tools in economics that provide insight into income distribution within a population. The Lorenz curve is a graphical representation of

income distribution, plotting the cumulative percentage of income against the cumulative percentage of the population [21]. In an ideal egalitarian society, the Lorenz curve would be a diagonal line indicating perfect income equality. However, in reality, it usually curves away from the diagonal line, reflecting varying degrees of income inequality. The Gini coefficient, derived from the Lorenz curve, is a numerical measure that quantifies this inequality which was introduced by the Italian statistician Corrado Gini in his work ‘Variability and Mutability’ published in Italian in 1912 [22]. It ranges from 0 to 1, where 0 indicates perfect equality, and 1 indicates extreme inequality. The current study used a similar concept to explain the geographical distribution of PDHFs in Riyadh city and showed that there was a moderate level of disparity in the distribution of PDHFs corresponding to the area (Gini coefficient = 0.357). To further illustrate this, as the number of PDHFs increases, the Lorenz curve shifts towards the upper-right portion of the graph. In other words, a greater proportion of PDHFs is concentrated in a smaller proportion of the area as the number of PDHFs increases. However, there was almost equality in the distribution of PDHFs in Riyadh city corresponding to the mean income (Gini coefficient = 0.207). In other words, as the number of PDHFs increases, the Lorenz curve shifts towards the upper-left portion of the graph. This movement signifies an improvement in the mean income according to the increase in the number of PDHFs.

This study is the first to evaluate the distribution of private dental healthcare facilities in Riyadh city using GIS and showed significant findings. However, in order to achieve optimal access to healthcare services, multiple factors in addition to the spatial distribution of PDHFs need to be analyzed, such as the actual number of dental chairs per facility, number of dentists and dental auxiliaries or clinicians’ full time equivalent (FTE) per facility, and the available dental specialties and types of services provided. In other words, the number of PDHFs may not accurately represent

the exact capacity (number of dental chairs or dentists); therefore, obtaining additional information about the actual number of dental chairs and dental staff and analyzing it with regard to the spatial distribution is recommended for future studies, which may help in reaching a more detailed view of the supply and demand in dental health care services. The findings of the present study established a foundation for the spatial distribution of PDHFs in Riyadh city. One of the limitations of this study is that it did not include the governmental dental healthcare facilities, which are considered a significant sector in providing healthcare services in Saudi Arabia in general and Riyadh city in particular. It would be beneficial to also map out and integrate the governmental facilities in Riyadh city to attain a more comprehensive perspective. Another limitation is having data collected from a single point in time. In other words, Riyadh city is rapidly developing, and new dental healthcare facilities are continually being established.

It is believed that a high quality of healthcare services increases individuals' utilization of dental services (Saeed and Mohamed, 2002; Butters and Willis, 2000). There are other factors involved as well, including access to care, financial reasons, and attitudes toward dental care (Al-Hussyeen, 2010). The number of private dental clinics in Saudi Arabia has steadily increased every year. However, patients seeking dental care in the private sector often lack basic information about the location and dental specialty offered in these clinics. Beside governmental database, there are lack of specific information needed about clinics registered. There are 236 dental clinics registered in MOH system in Riyadh city as of June 2016. The current study was able to collect data from 162 dental clinic centers and the rest; 74 elected not to participate for unknown reasons. According to MOH statistical book for the year 2015, a total of 3111 dentists were registered in the region of Riyadh. However, data findings from this study show that there are 877 dentists. The difference in the two numbers was mainly attributed that the current study surveyed dental clinics in Riyadh

city rather than Riyadh region included in MOH statistical book (KoSA, 2015). In addition, a system is lacking to verify information obtained or collected from these centers. The MOH aims to achieve the highest levels of transparency in 2030. Clearly, the current study suggests that work must be done to achieve this goal.

Results obtained from the current study indicated that most of dentists' workforce were male as compared to female (n = 536). Dental clinic centers reported that 341 dentists to be female gender. The social and religious factors dominated in Saudi Arabia society may play a key factor in choosing private dental clinic. Patient's perception and preference of either gender is lacking and need to be studied.

According to the current study, 40% of dentists working in private dental clinics were Syrians. There are significantly increasing in the number of Saudi dental graduates. Yet, it appears that the private dental clinics fail to recruit them. There are many explanations that can be elicited. Non-Saudi dentists may accept low wage and work for extended hours. Furthermore, Saudi graduates prefer government jobs for long term security and postgraduate education opportunities. The MOH plans to spend over 23 billion Saudi riyals on new initiative to meet 2030 vision (Vision, 2020). The current study gives a window to adopt plans to address this issue.

Last, the present study indicated that private dental clinics are not evenly distributed geographically in Riyadh city. The was also analyzed. It was found that among the 236 dental clinics registered, Olaya and Rawdha had the highest number of clinics: 49 and 45, respectively (Table 4).

## **5.2 Research Limitation**

The research has limitations, which must be carefully considered when interpreting the findings. These limitations stem from various factors related to data availability, the scope of the study, and the methods employed.

One significant limitation is the exclusive focus on private dental healthcare facilities (PDHFs). The study does not incorporate government-run clinics, mobile dental units, or dental schools. By narrowing the focus to only private sector facilities, the research omits a broader understanding of the entire dental healthcare system in Riyadh. This means the findings are not fully representative of the total healthcare landscape, which could influence the analysis of overall accessibility to dental services across the city.

Another limitation lies in the reliance on data provided by the Ministry of Health (MOH), which is used to identify active clinics. While the MOH database is a reliable source, it may not capture clinics that operate informally or are newly opened and not yet registered. This introduces the potential for missing data, which could affect the accuracy of the study's findings. Additionally, the study only focuses on operational clinics, excluding non-operational facilities or those with expired licenses, which could present a skewed view of the actual availability of dental services.

The geographic data utilized in the research is based on publicly available resources, such as the Riyadh municipality map and population statistics from the Zadd.910ths website. Although these resources are reputable and commonly used in urban planning studies, they are not immune to errors or outdated information. Changes in population, urban development, and infrastructure after the data collection period could impact the study's findings. Moreover, demographic data at the sub-municipality level may not fully account for localized population density variations within the districts, potentially affecting the accuracy of the analysis on accessibility.

The methodology used in this study, particularly the application of buffer zones around dental clinics, presents another limitation. While the creation of buffer zones is a standard approach in geographic accessibility studies, it does not take into account factors like road infrastructure, traffic congestion, and other barriers to transportation that could affect a person's ability to reach a dental clinic. The use of buffer zones assumes uniform accessibility across the area, which may not always be the case in a rapidly urbanizing city like Riyadh.

Additionally, the spatial analysis employed through Geographic Information Systems (GIS) has its own set of constraints. Although GIS tools like QGIS are highly effective for mapping and spatial data analysis, their accuracy depends on the precision of the input data. Any errors in the geographic coordinates of clinics could lead to distortions in the analysis of clinic distribution, which would, in turn, affect the overall conclusions regarding accessibility.

The study is also cross-sectional, providing a snapshot of the situation at a specific point in time. This approach does not account for changes that may have occurred before or after the data collection, such as the opening or closing of dental clinics, shifts in population movements, or modifications in healthcare policies. Consequently, the study's conclusions may not fully reflect long-term trends or future developments in the dental healthcare sector of Riyadh.

While the research provides valuable insights into the spatial distribution and accessibility of private dental clinics in Riyadh, these limitations must be taken into account when considering the results. Future research could address these limitations by including data from public sector clinics, incorporating more granular population and geographic data, and utilizing longitudinal methods to capture changes over time.

### **5.3 Conclusions**

The management and distribution of dental clinics across Riyadh have revealed a complex and multifaceted landscape, shedding light on both the strengths and gaps within the private dental healthcare system. The city, in its vast expanse, exhibits an uneven allocation of private dental healthcare facilities (PDHFs), with certain sub-municipalities, such as Rawdah, Olaya, and North Riyadh, seeing a higher concentration of clinics, while others, including Alsulay, Alshemaisi, and Alsharq, remain notably underserved. This geographical imbalance suggests that factors such as economic development, urban growth, and local demographics play a more significant role in the distribution of dental services than mere population density. While one might assume that a densely populated area would automatically correlate with an increased number of dental clinics, the findings challenge this assumption, indicating that other socio-economic variables must be considered when evaluating the availability of dental care in the city.

Despite the disparities in clinic distribution, a significant portion of Riyadh's population enjoys relative accessibility to dental services. Over eighty-six percent of the city's total area lies within a five-kilometer radius of a private dental clinic. This suggests that, overall, Riyadh's residents are well-positioned to access dental care with minimal effort. However, a closer examination of the one-kilometer buffer zone reveals that some areas, particularly those on the city's periphery, are not as fortunate. Sub-municipalities such as Alnaseem and Maather fare better in terms of access, highlighting that urban planning and infrastructural decisions still need to address the equitable distribution of healthcare facilities. This geographic inequity in dental service distribution speaks to a larger need for strategic urban planning that takes into account the varying access needs of all demographic groups across the city.

Further analysis of the PDHF-to-population ratios in different sub-municipalities paints a picture of both oversaturation and neglect in certain areas. For instance, districts like Olaya and

Ma'athar feature an abundance of dental clinics relative to their population size, suggesting a possible over-concentration of services. In stark contrast, regions like Alsulay and Alshemaisi experience a troubling lack of dental care options, as evidenced by their low clinic-to-population ratios. This imbalance calls attention to the possibility that some areas are underserved due to either an insufficient number of clinics or a lack of appropriate infrastructural development to support new establishments. As the city's population continues to grow and evolve, addressing these disparities becomes increasingly critical to ensuring that dental care remains accessible and sustainable.

The workforce within Riyadh's dental clinics further illustrates the complex nature of healthcare provision in the city. A significant portion of the dental workforce in Riyadh is made up of non-Saudi professionals, with many dentists hailing from countries such as Syria and Egypt. This demographic composition highlights the heavy reliance on foreign-trained professionals to meet the demands of the local market. Moreover, the data reveals that the majority of dentists in Riyadh are general practitioners, constituting roughly seventy percent of the workforce. While the general practitioner provides essential services, there is also a notable presence of specialists, such as orthodontists, prosthodontists, and oral surgeons, indicating that specialized care is available to those who require it. Nevertheless, the predominance of general practitioners over specialists may signal a tendency towards routine care and a potential gap in the provision of more complex dental treatments, which could pose challenges for addressing the more intricate needs of the population.

In the years spanning from 2019 to 2024, the number of private dental clinics in Riyadh has seen a steady increase, reflecting an undeniable demand for dental services. This upward trend suggests that the population's need for dental care is on the rise, driven by factors such as urbanization, growing awareness of dental health, and changing lifestyles. As certain areas

continue to see a proliferation of dental clinics, it is essential to analyze whether this trend is sustainable in the long term. The clustering of clinics in high-demand regions, such as Olaya and Rawdah, calls for an in-depth examination of the factors influencing clinic establishment, including market competition, population growth, and shifts in consumer behavior. Understanding these dynamics is vital for planning and forecasting the future needs of Riyadh's dental sector.

The correlation between income levels and access to dental care in Riyadh is also a critical aspect of this study. It is evident that wealthier sub-municipalities tend to boast a higher concentration of PDHFs, while lower-income areas experience a lack of sufficient dental facilities. This pattern is not unusual in cities around the world, where economic status often dictates the level of healthcare access one can enjoy. Riyadh's dental landscape is no exception, with economically prosperous areas gaining the lion's share of dental services, leaving residents of less affluent districts to navigate more limited options. Such inequality in healthcare access raises important questions about the need for policy interventions that promote fair and inclusive access to dental care, irrespective of income level.

In light of these findings, several recommendations emerge. First, there is a clear and urgent need to expand dental services in underserved sub-municipalities. The establishment of new clinics or the implementation of mobile dental units in areas such as Alsulay, Alshemaisi, and Alsharq could significantly improve access to care. Additionally, addressing the imbalance in the dental workforce by encouraging more Saudi nationals to enter the profession, particularly in specialized fields, could enhance the quality and availability of care across the city. Furthermore, regulatory measures should be considered to prevent the oversaturation of clinics in areas like Olaya and Rawdah, ensuring that dental services are distributed in a more balanced and sustainable manner.

Lastly, leveraging technology, such as telemedicine and online consultations, could help bridge the gap in care access, particularly for residents in more remote or underserved areas.

In conclusion, Riyadh's dental healthcare system is marked by a complex web of factors that influence both the availability and quality of care. While the city enjoys a relatively high level of access to dental services, there are notable disparities that require thoughtful attention and intervention. Moving forward, a more strategic approach to dental clinic distribution, workforce development, and healthcare policy will be essential to ensuring that Riyadh's residents have consistent and equitable access to the care they need. As the city continues to grow and evolve, it is vital that dental care keeps pace with these changes, ensuring that no community is left behind.

#### **5.4 Recommendations**

The findings of this study suggest several important areas for improvement in the provision of dental care across the city. The following recommendations are proposed to address the current disparities and ensure that dental services are more accessible, sustainable, and equitable for all residents:

First, expanding dental services in underserved areas should be prioritized. The analysis shows that several sub-municipalities, such as Alsulay, Alshemaisi, and Alsharq, lack sufficient private dental clinics to meet the needs of the population. Local government authorities, in collaboration with private sector stakeholders, should focus on incentivizing dental professionals to establish clinics in these underserved regions. This can be achieved through subsidies, tax incentives, or facilitating easier access to commercial space for clinic establishments. Additionally, mobile dental units or pop-up clinics can be deployed in these areas as a short-term solution, bringing dental care directly to residents who are geographically disadvantaged.

In parallel, there is a need to address the oversaturation of clinics in areas like Olaya, Rawdah, and North Riyadh, where a high density of dental facilities exists in comparison to the population. Regulatory measures should be introduced to prevent the over-concentration of dental clinics in these regions. One approach could be the implementation of zoning laws or guidelines that promote the distribution of clinics in a more balanced way across Riyadh. This could encourage dental professionals to establish their practices in areas where there is a genuine demand but a shortage of services, ensuring that access to dental care is not limited to just a few areas of the city.

Moreover, addressing the workforce imbalance is critical to ensuring the quality of dental care in Riyadh. The majority of dentists in Riyadh are general practitioners, with a smaller proportion specializing in more complex areas like orthodontics or oral surgery. To meet the growing demand for specialized care, there should be concerted efforts to encourage dental professionals to pursue further specialization. This could be achieved through scholarships, fellowships, and specialized training programs tailored to the needs of the Riyadh dental market. Additionally, increasing the number of Saudi-trained dentists, particularly specialists, would help reduce the reliance on foreign-trained professionals and improve the local workforce's sustainability.

Another recommendation is the integration of modern technology into dental practices to improve both accessibility and efficiency. With technological advancements in telemedicine, online consultations, and digital dental records, Riyadh's dental clinics can streamline patient care, reduce waiting times, and offer more convenient services to patients in remote or underserved areas. Tele-dentistry can be an effective tool in bridging the gap between patients and dental professionals, allowing for virtual consultations, follow-ups, and preventive care advice.

Moreover, the implementation of digital appointment scheduling systems, patient portals, and electronic health records can further enhance patient satisfaction and clinic management.

It is also recommended that public-private partnerships be leveraged to enhance dental care accessibility in Riyadh. Collaboration between government bodies and private dental clinics can result in more equitable access to care. Government initiatives could provide subsidies to private clinics willing to expand into underserved regions or offer services at a reduced cost for low-income residents. Additionally, government-sponsored awareness campaigns about dental hygiene and preventive care could help improve public knowledge about the importance of regular dental visits and the availability of services across the city.

To ensure that dental services remain relevant and effective, a more comprehensive and detailed approach to urban planning should be undertaken. As Riyadh continues to expand, future urban developments must take into account the spatial distribution of healthcare facilities, including dental clinics. Urban planners should consider integrating healthcare infrastructure within new residential and commercial developments to ensure that dental services are readily available to all residents, particularly in rapidly growing suburban areas.

Lastly, continuous monitoring and evaluation of the dental healthcare sector should be instituted to assess the effectiveness of the implemented strategies and ensure that the evolving needs of Riyadh's population are being met. Regular surveys, patient feedback, and performance assessments can help identify gaps in service delivery, allowing policymakers and dental professionals to make necessary adjustments to improve care.

The recommendations outlined here aim to promote a more equitable, accessible, and sustainable dental healthcare system in Riyadh. By addressing issues related to clinic distribution, workforce composition, technological integration, and collaboration between the public and

private sectors, Riyadh can develop a dental care environment that meets the needs of its diverse and growing population. As the city continues to expand, it is essential that dental services evolve to ensure that every resident has access to the care they deserve.

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