



# Application of Geographic Information System Marks a Revolutionary Change in Dental Sciences

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## Abstract

There is rapid development in science and its innovations. Consequently, today's dental science is a pure amalgamation of recent advances and applications. With this very conception, dental science has developed far way ahead. This combination and blending with various other sciences give a new meaning and beauty to today's dentistry.

Among the recent inventions, there emerges geographic information system (GIS), which is a collection of computer hardware and software, geographic and tabular data, and personnel and knowledge in an organized manner that is designed to capture, store, manipulate, update, analyze, and display spatial data. The most significant and remarkable outcome in the history of medical and dental sciences is the application of GIS and its analysis in the healthcare system.

The potential of GIS is well accepted and its full use in healthcare services is yet to be explored. It is a tool that links statistical and thematic data to geographic locations on maps and thus represents and symbolizes data in a visual format. The article gives a review of the various uses of GIS in the dental sciences. The adoption and recognition of GIS by oral healthcare researchers and policymakers will be a major revolutionize pace in the dental health services systems.

**Keywords:** Geographic information system (GIS), remote sensing, geospatial health research, spatiotemporal dimension, geomapping

## Introduction

With the invention of recent technologies and their expertise, dentistry has evolved way beyond in the twenty-first century. The recent advancement in multidisciplinary approaches has touched modern dentistry leading to a new horizon, thereby changing the concept in dentistry slowly.

Within such new approaches, tools for geoprocessing have appeared, among which geographic informa-

tion system (GIS) stands out as a novel technology, which explores these relationships and thus contributes to building a better understanding between the environment and health.[1] GIS also provides the healthcare services with rapid information about exact locations where the problem exists to a larger extent, thereby accelerating the process of planning, monitoring, and evaluating the oral health services required. Recent studies show the importance of using GIS as a method increasingly accepted for this type of strategy and as a

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tool that is also used in various epidemiological studies. It provides important information regarding the analysis of various diseases and their geographical distribution and about the interrelationship of diseases with social, economic, environmental factors, along with the pathogenic agents, and also in elucidating the mechanism of diseases.[2,3] Recent development in GIS has made the accessibility to spatial data possible. It has also enabled the study of epidemiology spatiotemporal dimension of the environment due to the development of spatial analysis, which was not possible before.[4,5] GIS has been used to map populations with frequently occurring infectious diseases such as malaria, AIDS, and malnutrition in children. It is apparent that GIS is being used for health studies by many researchers in varied areas of specialization. Their potential has been clearly demonstrated in many research projects and scientific papers. Among specialists in the area, GIS has attained an outstanding place as it offers information regarding allocation of health resources, its understanding, planning, and monitoring, and above all its utilization in areas of greatest concern.[6] Furthermore, a database, when linked to facilities such as the GIS, would enable connecting individuals with the environment to provide an understanding of the spatial distribution of patients affected by a certain disease.[7-9] It is important to analyze the disproportion and spatial distribution of oral diseases for the proper allocation of resources to the deprived group.[10]

### **What is geographic information system?**

GIS comprises a computer-based system used for the input, storage, maintenance, management retrieval, analysis, and output of geographic or location-based information.[11] It facilitates determining spatial relationships by a simultaneous display of an array of data on multiple maps and is identified as the basis for data linkage, analysis, and correlating these data in the twenty-first century.[12] The term “geographic information system” was first used by Roger Tomlinson in the year 1968 in his paper “A Geographic Information System for Regional Planning”. [13] However, the first ever application of spatial analysis in epidemiology was in 1832, “Rapport sur la marche et les effets du choléra dans Paris et le département de la Seine”. [14] The earliest and initial successful uses of a geographic methodology in epidemiology were in 1854 when John Snow studied the source of a cholera outbreak in London by marking various points on a map representing areas where the cholera victims lived and connecting these with the nearest source of water. There is a strong asso-

ciation among health, environment, and geography. The places and environment where the people live very much affect the distribution of diseases and health outcome. For example, the characteristics of a place whether it is urban, rural, arid, or tropical influence the disease patterns, mortality, morbidity, life expectancy, education, income, and lifestyle, among many other things.[15] The geography of healthcare comprises the analysis of spatial organization (number sizes, types, and locations) of the available health services, how and why spatial organization changes over time, how people gain access to health services, and the impacts on health and well-being.[16] A set of tools is provided by GIS and related spatial analytic techniques, which describe and give an understanding of the changing spatial organization of healthcare. It also facilitates us to understand its relationship to health outcomes and access, thus helping in exploring how dental and healthcare delivery can be improved. It is a tool that links statistical and thematic data to geographic locations on maps and thus represents and symbolizes data in a visual format. These help in the detection of areas of higher priority that needs health intervention the most. Identification of health indicators, including specific unmet health needs, detect areas where health facilities and services are absent, health hazards identification, distribution of certain specific diseases, poverty and other factors, and any association between them can be made up easier with the help of these maps.

### **Application and limitations of GIS in dental sciences**

For a better understanding of the oral health/disease process, it becomes interesting to explore the relationship between space and community health. Detailed analysis of the spatial distribution and pattern of inequality of oral diseases is fundamental for the allocation of resources to areas with the greatest social privation, leading to greater efforts to address the problems. [17] Recent studies have shown the importance of the use of GIS in this type of strategy, as a method increasingly accepted and used in epidemiological studies, providing important information with regard to the analysis of the geographic distribution of diseases, their associations with social, economic, and environmental factors, and pathogenic agents, as well as elucidating the mechanisms of diseases.[2,3] GISs are still infrequently used in public health, especially in dental studies; however, the method has attained an outstanding place among professionals in the area due to the inventive information it can offer with regard to understanding, planning, monitoring, and allocation of health resources.

Dental healthcare providers in today's advanced scenarios are exploring novel forms of healthcare services, emerging innovative systems, and thereby the persistently high costs of dental care are raising concerns about quality, effectiveness, and access. GIS and related spatial analytic techniques provide a set of tools that describes and helps in understanding the changing spatial organization of dental and healthcare and gives an idea about how healthcare services can be delivered more efficiently. Research studies in GIS are also performed to analyze the need for dental care. They also highlight how GIS is being used to study geographical access to dental services and to understand disparities in access among population groups. Their main focus is on the proper utilization of GIS to analyze geographic variations in dental care services and emphasize the use of GIS to evaluate and plan dental health facilities. They can also be used to explore and determine the population among hospital service areas. Dentist per population group among hospital service areas can also be determined; thus, such data show some comparative information that may be useful out there for our human welfare agencies and planning dental care services to the population area wise. They have also been applied to investigate the regional incidences of oral cancer.[18]

For many years, GIS has been used to co-relate the diversity in population and environmental information to evaluate the various dimensions of dental care needs and services.[19] "Community environmental oral health profile," describing demographic, economic, and lifestyle characteristics of the population, as well as its exposure to the potential environmental hazards and risks, is an example for the same.[20] As GIS enables digital information on morbidity, demographics and utilization become more widely available. This incorporates dental healthcare need in a GIS-based decision support tool that helps the communities and concerned authorities to examine the child oral healthcare needs its accessibility, services, and availability. These informative and valuable maps can start putting them out there onto the Internet for people to use instantly.

The provision of oral healthcare is a complex task, particularly when the disease burden is unevenly distributed through the population and even in a distribution that does not match the population distribution. In 2011, Kruger et al[21] examined and illustrated the distribution of private dental practices in Western Australia, using the modern GIS tools. The study concluded that 75% of the dental practices were located within 32 km and 95% were within 256 km of the Perth General Post Office. In metropolitan Perth, in areas with residents of

lower socioeconomic status, fewer dental practices were located, whereas in the inner city region the density of these dental practices was more. In the USA too, few studies have explored this location-based tool in determining the accessibility to dental services and also the distribution and demographics of dentists.[22] According to a recent Australian study regarding the accessibility of public dental services, in comparison with the states of Victoria and Queensland, Western Australians appears to be in a poor position of dental services. Thus, there is a need to develop better strategies to retain dentists and dental health services in these areas. [23] Lahti et al[24] studied the area-based variation and deviation of factors related to oral health among 6-year olds in Kemi, Finland. The areal factors included in the study were percentage of unemployed, annual gross income, number of persons economically dependent on one employed person, and the percentage of household-dwelling units with the poor standard of equipment. They concluded the study in Kemi and found out that the poor areal socioeconomic living standards were not associated with poor oral health as reported elsewhere. This could be well explained and demonstrated by the fairly homogenous structure of Finnish society.

Strömberg in 2012 conducted a study to develop the geomap concept, studying the time trends in caries risk and also by analyzing the epidemiological data from preschool residents in the region of Halland, Sweden, thus demonstrating the novel concept. He concluded that geomapping can be helpful in studying the variation in caries risk over a period of time. Thus, with the help of geomapping, it is convenient to evaluate the efficacy and effectiveness of tailored health promotion and preventive care in the child population.[25] Pereira et al[6] also investigated and examined the distribution profile of dental caries and its link with socially deprived areas at an individual and a contextual level. Dental caries and the care index were examined using the DMFT index to study and analyze the access to dental care services. The study resulted that variables were associated with better oral health status at an individual level, whereas it was not so at the contextual level. This also determined that in comparison with the deprived outlying district, the central district with a better social condition has better oral health status. GIS approach is also used to evaluate the concentration of fluoride in groundwater and the occurrence of dental fluorosis and its geological distribution.[26] Podskalniy et al[27] used GIS to "explore the spatial association between neighborhood contexts and oral health outcomes in a Pediatric Population".

Dentistry requires a very precise diagnosis and location of anomalies such as cavities. This has led to GIS making routes in dentistry, where dentists now use spatial technologies for dental surgery and diagnosis. Anatomical dental charting of patients' teeth and analysis of what can be done for intervention are one area where GIS has been used. In this method, patients' teeth are overlain for planning purposes. Mapping features and quarrying data are some of the processes that can aid a dentist in recognizing their patient and planning dental intervention.[28]

3D mapping is another area of high interest in dentistry. As 3D imaging allows capturing the shape of the tooth, it can assist in mapping genetic variations. Different teeth are then analyzed and compared for anomalies as a way to identify genetic variation through the morphology of teeth differences. Having 3D grids overlain with tooth morphology helps to automatically measure variations from expected norms.[29]

Apart from several advantages, GIS has some limitations. GIS, being a relatively new technology, has very limited skilled and trained manpower. The lack of trained and skilled manpower has increased the demand, which is beyond the reach of most health department budgets.[30] While it is possible to find sources of training for GIS generally, it is far more difficult, if not impossible, for most individuals to find training on the use of GIS for understanding dental issues. [30] There are limitations of data due to which GIS users have faced problems for decades in both developed and developing nations. Finding the money to collect new data and to convert paper maps and data into digital format continues to be a problem. In many cases, digital data do exist, but there are issues, such as confidentiality and national security, which have prevented their use by dental and health-related departments.[30]

## Conclusion

GIS can be considered as one of the most adequate strategies for evaluating and assessing the process of inequality in the distribution of various oral diseases that can be observed worldwide. GIS emphasizes the populational approach with the fundamental principle to rescue the role of the sociocultural environment in the distribution and determination of oral-related diseases. Its application has great potential in shaping modern dentistry, which has generated great interest and attention among researchers. There should be more of such innovative research using the application of GIS in dental sciences so that the maximum benefit can be explored and defined for mankind.

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