Original Article

Mapping the Distribution of Dentists and Dentist-to-Population Ratios in Chennai City Using Geographic Information System

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A B S T R A C T

Background: The distribution of dental services within large urban centres strongly influences access to oral healthcare, yet routine workforce planning often relies on aggregate registration data rather than spatially localized service availability. Geographic information systems can provide a more realistic view of service distribution.

Objectives: To map the distribution of dental clinics across the zones of Chennai city and to estimate dentist-to-population ratios using a geographic information system-based approach.

Methods: This cross-sectional study used publicly available population data from the Greater Chennai Corporation and ward-wise Google Maps searches to identify dental clinics across 10 corporation zones. Four trained and calibrated investigators independently collected clinic data using standardized search terms. Descriptive statistics were used to summarize clinic distribution and zone-wise dentist-to-population ratios. Inter-rater and intra-rater reliability were assessed using Cohen's kappa and Cronbach's alpha.

Results: Chennai had a total population of 5,633,496 and 1,432 mapped dental clinics. Zone 4 contained the highest number of clinics (223), whereas Zone 9 had the lowest (100). Assuming one dentist per clinic, the overall dentist-to-population ratio for the city was 1:3934. Marked inter-zonal variation was observed, with more favorable ratios in Zones 6 and 7 and less favorable ratios in Zones 5 and 9. Reliability of clinic identification was high, with perfect inter-rater agreement ($\kappa = 1.00$, $p < 0.001$) and excellent internal consistency ($\alpha = 0.92$).

Conclusion: GIS-based mapping demonstrated substantial inequality in the spatial distribution of dental clinics across Chennai. City-level workforce counts alone can mask local imbalances in service availability. GIS offers a practical approach for urban dental workforce assessment and can support evidence-based planning for more equitable access to oral healthcare.

Keywords: Chennai; dental workforce; dentist-to-population ratio; geographic information system; oral health services.

INTRODUCTION

Oral health is an integral component of general health, functional well-being, and quality of life. However, access to dental services remains uneven within and across populations, especially when the distribution of providers is not aligned with the geographic distribution of people in need [1-3]. Dental workforce planning has therefore become an important area in public health dentistry because decisions regarding the number, location, and deployment of dental professionals' influence

both service availability and continuity of care [1,2]. Traditional manpower planning models have commonly relied on crude dentist-to-population ratios, but such ratios, when interpreted without spatial context, can obscure local shortages and overconcentration of providers [1,2]. This is particularly relevant in rapidly urbanizing settings where population density, transportation access, private sector clustering, and socioeconomic gradients shape real-world utilization of care [3].

India has experienced substantial growth in dental education and dental workforce output over the past two decades [4-7]. Despite this expansion, important concerns persist regarding maldistribution of dental professionals, concentration of services in urban and commercially favorable locations, limited public sector absorption, and persistent disparities in access to oral healthcare [4,6,7]. The challenge is therefore not simply the absolute number of dentists, but whether those dentists are available in places where the population can realistically access them [4,6]. Previous commentaries and reviews from India have emphasized that workforce planning should move beyond registration counts and should account for actual practice patterns, geographic inequity, and service delivery realities [5-7].

Geographic information systems (GIS) offer a useful analytical framework for studying the location and accessibility of health services. In dentistry, GIS-based methods have been used to map the distribution of dentists, identify underserved areas, and estimate service accessibility in relation to population clusters [8-11]. Studies from Ohio and Mississippi demonstrated that GIS can identify geographic disparities that remain hidden in conventional summaries of provider numbers [8-10]. Such approaches are especially valuable in metropolitan cities, where service density can vary considerably between administrative zones despite a seemingly favorable overall workforce profile.

Chennai is one of India's largest metropolitan cities and hosts a large number of dental practitioners and training institutions. Nevertheless, zone-level information on the spatial distribution of dental clinics is limited. Understanding where clinics are located relative to population concentration is important for rational workforce planning, equitable service delivery, and local public health decision-making. Therefore, the objectives of the present study were to map the distribution of dental clinics across Chennai city using a GIS-based approach, to estimate zone-wise dentist-to-population ratios under different staffing assumptions, and to assess the reliability of clinic identification using repeated investigator-based searches.

METHODOLOGY
Study design and setting
This was a cross-sectional descriptive study undertaken to analyse the spatial distribution of dental clinics and dentist-to-population ratios in Chennai city using a geographic information system-based approach. Chennai, administered by the Greater Chennai Corporation, was divided into 10 corporation zones for the present analysis. The city-level population considered for the study was 5,633,496 based on the available corporation population dataset derived from the 2011 census.

Data sources
Population data for each zone were obtained from the Greater Chennai Corporation website. Information on dental clinics was collected using Google Maps on Android smartphones, as this platform provided a readily available, ward-searchable geoinformation interface. The use of GIS-based mapping for assessing dental service accessibility and provider distribution has been described in previous dental workforce studies and informed the present methodology [8-11].

Identification of dental clinics
Four trained and calibrated investigators participated in the study. A standardized search strategy was used to identify dental clinics within each administrative unit. Investigators searched ward or locality names using a consistent format such as "dental clinics in [ward/locality name]" and recorded the number of identifiable clinics returned on Google Maps. Searches were performed independently to reduce observer bias. Duplicate assessments were undertaken to strengthen data verification. Clinics identified through the mapping platform were entered into a structured Microsoft Excel sheet zone-wise and then aggregated to obtain the total number of clinics in each corporation zone.

Reliability assessment and data validation
To assess agreement between observers, independent clinic counts generated by investigators were compared using Cohen's kappa statistic. Repeated searches conducted by the same investigators at different times were used to assess consistency of the search method. Cronbach's alpha was used as an indicator of internal consistency across repeated observations. The final zone-wise clinic counts used for analysis were compiled after reconciliation of the independently collected datasets.

Statistical analysis
Descriptive statistics were used to summarize the number of clinics and population in each zone. Dentist-to-population ratios were calculated for each zone and for the city as a whole under four assumptions: one dentist per clinic, 1.5 dentists per clinic, two dentists per clinic, and three dentists per clinic. The assumption of 1.5 dentists per clinic was included to

reflect the possibility that some clinics functioned with more than one dentist. Results were presented as frequency distributions, zone-wise ratios, and narrative comparison of more and less favorably served zones.

Ethical considerations

The study was based entirely on publicly available population data and publicly accessible online map listings. No patient-level information, personal health information, or direct human participation was involved. Therefore, formal participant consent was not applicable for this analysis.

RESULTS

A total of 1,432 dental clinics were mapped across the 10 zones of Chennai, serving a reported city population of 5,633,496. On the basis of clinic counts alone, the overall clinic-to-population ratio was 1:3934. Inter-rater agreement between investigators was perfect [$\kappa = 1.00$, $p < 0.001$], and repeated assessment demonstrated excellent internal consistency [Cronbach's $\alpha = 0.92$], supporting the reliability of the mapping process.

Marked inter-zonal variation was observed in clinic distribution. Zone 4 recorded the highest number of clinics [223] for 614,846 residents, whereas Zone 9 had the lowest clinic count [100] for 518,936 residents. Zone 5 contained the largest population [655,900] but only 125 clinics, indicating relatively lower clinic availability. In contrast, Zones 6 and 7 had smaller populations with 153 and 140 clinics, respectively, reflecting comparatively greater clinic density. The observed zone-wise distribution of population, clinic numbers, and clinic-to-population ratios is presented in Table 1.

Table 1. Zone-wise distribution of population, mapped dental clinics, and observed clinic-to-population ratios in Chennai

Zone	Population	Dental clinics	Clinic-to-population ratio
1	519,386	117	1:4,439
2	435,845	144	1:3,027
3	573,596	146	1:3,929
4	614,846	223	1:2,757
5	655,900	125	1:5,247
6	342,813	153	1:2,241
7	315,956	140	1:2,257
8	542,594	154	1:3,523
9	518,936	100	1:5,189
10	518,936	130	1:3,992

Note: Overall reported city population = 5,633,496; total mapped dental clinics = 1,432; overall clinic-to-population ratio = 1:3,934. Ratios are based on observed clinic counts and are rounded to the nearest whole number.
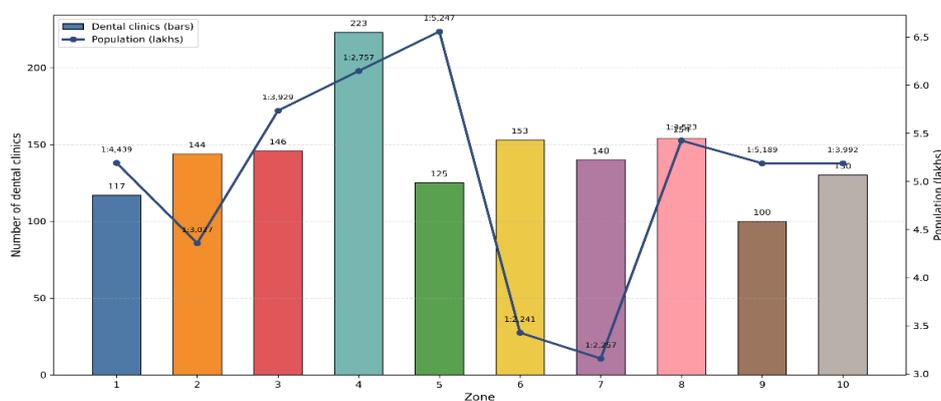

Figure 1: Zone-wise distribution of population, mapped dental clinics, and observed clinic-to-population ratios in Chennai

To explore potential workforce availability under varying average staffing patterns, modeled dentist-to-population ratios were derived using alternative clinic staffing scenarios. Across all modeled scenarios, the relative pattern remained consistent, with Zones 6 and 7 demonstrating more favorable estimated coverage and Zones 5 and 9 showing less favorable coverage. At the city level, the estimated ratio improved from 1:3934 under the single-dentist-per-clinic model to 1:2623, 1:1967, and 1:1311 under the 1.5-, 2-, and 3-dentist scenarios, respectively. These modeled estimates are summarized in Table 2.

Table 2. Estimated dentist-to-population ratios across Chennai under alternative clinic staffing scenarios

Zone	Population	1 dentist/clinic	1.5 dentists/clinic	2 dentists/clinic	3 dentists/clinic
1	519,386	1:4,439	1:2,959	1:2,220	1:1,480
2	435,845	1:3,027	1:2,018	1:1,513	1:1,009
3	573,596	1:3,929	1:2,619	1:1,964	1:1,310
4	614,846	1:2,757	1:1,838	1:1,379	1:919
5	655,900	1:5,247	1:3,498	1:2,624	1:1,749
6	342,813	1:2,241	1:1,494	1:1,120	1:747
7	315,956	1:2,257	1:1,505	1:1,128	1:752
8	542,594	1:3,523	1:2,349	1:1,762	1:1,174
9	518,936	1:5,189	1:3,460	1:2,595	1:1,730
10	518,936	1:3,992	1:2,661	1:1,996	1:1,331

Note: Values in Table 2 are modeled estimates derived from the observed number of clinics and alternative average staffing scenarios. They do not represent directly observed dentist counts. Overall city-level estimates based on the reported population were 1:3,934, 1:2,623, 1:1,967, and 1:1,311 under the 1-, 1.5-, 2-, and 3-dentist scenarios, respectively. Ratios are rounded to the nearest whole number

DISCUSSION

The present study mapped the distribution of dental clinics across Chennai and demonstrated that the city's dental workforce, when estimated through clinic locations, was not evenly distributed across corporation zones. Although the overall dentist-to-population ratio appeared favorable at the city level, zone-wise analysis showed clear spatial imbalance. This finding reinforces a central issue in dental workforce planning: aggregate provider counts do not necessarily represent real access to care because they fail to show where services are concentrated and where gaps persist [1,2]. In large urban settings, localized distribution is often more informative than citywide totals.

The observed clustering of clinics in selected zones is consistent with the broader literature on oral health access and workforce distribution. Previous studies have shown that provider availability frequently accumulates in commercially attractive or better connected localities, while other areas experience relative underservice [3,6,7]. In the present analysis, Zone 4 had the highest number of clinics, whereas Zones 5 and 9 had less favorable dentist-to-population ratios under the one-dentist assumption despite serving substantial resident populations. By contrast, Zones 6 and 7 appeared more favorably served relative to their population size. This pattern suggests that Chennai does not simply face a shortage of dental clinics; rather, it demonstrates an uneven spatial concentration of available services.

Our findings parallel GIS-based studies conducted in other regions. Susi and Mascarenhas, Horner and Mascarenhas, and Krause et al. showed that geospatial methods can identify underserved pockets even in areas with a seemingly adequate absolute number of dentists [8-10]. Workforce tracking studies from Iowa and reviews of rural oral health services in the United States similarly emphasized that access depends not only on workforce size but also on provider location, travel burden, and community context [12,13]. More recent geo-spatial studies from India and Australia have also shown that dental services tend to cluster in urbanized and economically stronger areas [11,14]. The present study extends this evidence to Chennai and supports the use of spatial analysis for metropolitan dental planning.

These findings are especially relevant in India, where rapid growth in dental education and workforce output has not consistently translated into equitable service deployment [4-7]. Registration figures alone can overestimate actual

community availability because they do not distinguish active clinical practice from academic, administrative, migratory, or non-practicing status [6,7]. GIS-based clinic mapping offers a more practice-oriented perspective by focusing on service points that are identifiable to the public. The high inter-rater agreement and excellent internal consistency observed in this study further support the reliability of the standardized search approach. Taken together, the results suggest that GIS can serve as a practical and scalable tool for identifying local service gaps and informing targeted oral health workforce planning in major Indian cities.

LIMITATIONS

This study relied on publicly available population data and Google Maps listings, which can omit unregistered, newly opened, or temporarily closed clinics. The analysis assumed one dentist per clinic for the primary ratio, although staffing patterns differ across practices. Dental services delivered through hospitals, teaching institutions, primary health centres, and outreach units were not included, so the reported ratios reflect mapped clinic availability rather than the full workforce in Chennai.

CONCLUSION

This GIS-based assessment showed that Chennai has a substantial dental service presence, but the distribution of clinics is uneven across corporation zones. While the overall city ratio appears acceptable, zone-level analysis revealed clear clustering of services in some areas and relative shortfall in others, especially where large populations are served by fewer clinics. These findings indicate that registration counts or citywide totals alone are insufficient for workforce planning. Spatially anchored monitoring can better identify local gaps, support targeted expansion of public and private services, and improve equity in oral healthcare access. GIS-based workforce assessment is feasible, practical, and well suited for informing urban oral health policy and resource allocation in India.

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