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Geospatial analysis of dental service utilization: A retrospective study

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Abstract:

Geographic accessibility strongly influences the utilization of public dental healthcare services. This retrospective study analyzed records of 10,300 patients attending GGH, Yanam, from January 2025 to January 2026. Demographic, residential and treatment data were mapped using Google Maps, QGIS and analyzed in IBM SPSS version 25. Most patients lived within 5 km (59.60%), mainly in the eastern sector (49.10%) and extractions were the commonest treatment (62.17%). Thus, data shows the impact of proximity on dental service utilization and support strengthening preventive oral healthcare.

Keywords: Geo-spatial analysis, dental service utilization, distance travelled, government hospital, oral health, geographic information system (GIS)

Background:

The World Health Organization (WHO) defines oral health as the state of the mouth, teeth and orofacial structures that support vital bodily processes including speaking, breathing and eating. It encompasses psychosocial aspects such as wellbeing, self-assurance and the capacity to engage in social and professional activities without pain, discomfort or shame. Oral health is vital to overall health, facilitates people's capacity to reach their full potential in society and stays dynamic throughout life [1]. Approximately 3.5 billion individuals worldwide suffer from oral diseases and almost 2.3 billion of them have untreated dental caries [2]. According to the 2019 Global Burden of Disease Study, untreated dental caries in permanent teeth is the most common illness in the world [3]. Even though India's healthcare system has advanced significantly, the oral health situation still faces several obstacles. In the Indian landscape, the challenge of managing oral disease prevalence is amplified by vast demographic expansion and socio-economic diversity. National health surveys and regional academic literature consistently indicate stark inequities in oral health status across states and territories. For instance, dental caries prevalence and periodontal vulnerabilities show significant unevenness, influenced closely by family income levels, local water fluoridation parameters and gender disparities [4]. Furthermore, the structural delivery of dental care in the country is heavily stratified, with an overwhelming concentration of private practitioners in highly urbanized centres, leaving public healthcare institutions to carry the primary burden of serving rural, semi-urban and economically marginalized populations. To address these structural disparities, public health research has increasingly integrated advanced technological frameworks, chief among which is the Geographic Information System (GIS) and geospatial analysis. GIS functions as an enabling technology that links conventional non-spatial clinical data with precise geographical coordinates, facilitating the visual and mathematical mapping of healthcare trends [5]. In Indian public health research, geospatial methods have been applied across numerous domains, such as tracking infectious disease outbreaks, calculating maternal-child health metrics and

mapping oncology incidences, offering public health specialists a powerful diagnostic lens to identify localized hotspots and optimize resource allocation [6]. The integration of GIS has pioneered new methodologies for examining epidemiological patterns and systemic inefficiencies. Researchers rely on geospatial frameworks to plot oral disease risk indices, analyses spatial autocorrelation and audit the exact distribution of the dental workforce relative to population densities [7]. By executing thematic mapping and proximity modelling, these systems present complex epidemiological data in simplified, actionable visualizations. This helps healthcare administrators locate "dental deserts," assess whether public oral health facilities adequately cover local sub-districts and systematically direct scarce preventive programs toward high-risk communities [8]. Long travel distances act as severe barriers, frequently restricting individuals from seeking timely preventive care and forcing them to delay treatment until acute, irreversible dental pain or advanced pathology develops. Consequently, understanding how travel distance impacts healthcare-seeking behaviour remains paramount, as even robust infrastructure fails if the travel burden exceeds the practical threshold of vulnerable patient populations [9]. Therefore it is of interest to assess the distance travelled by patients seeking dental care at GGH, Yanam and to evaluate the types of dental treatments availed by these patients.

Materials and methods:**Study design and setting:**

A retrospective cross-sectional geospatial analysis was conducted in the Dental Outpatient Department of Government General Hospital, Yanam to assess the distance travelled by patients to avail dental treatment.

Ethical consideration:

Ethical approval was obtained from the institutional ethical committee (ANIDS/IEC/2025039). Permission was obtained from the authorities of Government General Hospital, Yanam, to use the data for research purposes and all patient details were kept confidential.

Study period:

Data collection and geo-spatial analysis were carried out for patients attending the OPD between January 2025 and January 2026.

Study population:

The study population consisted of patients who attended the dental OPD at GGH, Yanam.

Inclusion criteria:

Dental OPD records from January 2025 to January 2026; patient records with complete residential address details; and patients who had undergone treatment

Exclusion criteria:

Patient records with incomplete or missing address information were excluded.

Data collection:

From the secondary data extracted from dental OPD records, age, gender, residential address and treatment rendered were recorded. Treatments were categorized into scaling, restorations, extractions, prosthetic procedures, management of facial pain, biopsies, suturing of lacerated wounds and other dental services.

Statistical analysis:

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 25. Descriptive statistics such as frequencies, percentages and mean were calculated.

Geo-spatial analysis:

The distance travelled by patients was obtained using Google Maps from their residential address to the Government General Hospital (GGH), Yanam, India. The shortest travel distance was recorded in kilometres and the type of dental service availed was noted against the distance travelled. Geo-spatial analysis was performed using QGIS software v4.0 to enable accurate distance-based calculations.

Results:

Based on the inclusion criteria, 10,300 records were obtained from the dental OPD. Patients were divided into groups based on the treatments they received. **Table 1** outlines the baseline demographic characteristics of the studied population (N = 10,300), categorized by age cohorts and gender. **Table 2** The single largest age group comprised individuals aged 31-45 years (n = 3,097, 30.06%), followed by the 16-30 years cohort (21.28%) and the 46-60 years cohort (20.67%). Geriatric patients older than 60 years accounted for 19.85% (n = 2,045), while paediatric patients under 15 years constituted the smallest portion at 8.14% (n = 837). The sample showed an even distribution between adult male (n = 4,117, 39.97%) and adult female (n = 4,088, 39.69%) patients. Among the paediatric segments, female children represented 11.65% (n = 1,200) and male children 8.69% (n = 895). Extraction emerged as the most frequently availed treatment by a substantial margin, accounting for 62.17% (n = 6,403) of the total clinical caseload, highlighting a high

prevalence of advanced oral disease requiring radical surgical care. Oral prophylaxis (scaling) was availed by 12.96% (n = 1,335), closely followed by restoration at 12.78% (n = 1,316). Root canal treatment was performed for 4.42% (n = 455) and prosthetic rehabilitation for 3.30% (n = 340). Oral and maxillofacial biopsy for suspected lesions constituted 1.08% (n = 111) and the remaining 3.30% (n = 340) received emergency or therapeutic management grouped under "others," including acute trauma stabilization, facial pain management and soft-tissue laceration suturing. **Table 3** illustrates the geographical distribution of the 10,300 study participants according to their distance and direction from Government General Hospital (GGH), Yanam, which served as the central geographic hub. A pronounced concentration of patients was observed within 5 km of the hospital, particularly in the eastern direction, where 4,826 patients (46.85%) originated from 54 locations. In comparison, 720 patients (6.99%) from nine locations were located south of the hospital, while 593 patients (5.76%) from six locations were located west of the hospital; no participants were recorded within 5 km north of GGH. Among participants residing 6-15 km from the hospital, the largest proportion was from the north (981; 9.52%), followed by the west (515; 5.00%), east (231; 2.24%), and south (64; 0.62%). In the 16-25 km zone, the western direction contributed the highest number of participants (1,489; 14.46%), whereas the south and north contributed 188 (1.82%) and 54 (0.52%), respectively. Between 26 and 35 km, 400 participants (3.88%) were located south of GGH and 100 (0.97%) west of the hospital. Very few participants originated from 36-45 km (38; 0.37%), while only 101 participants (1.00%) were located beyond 45 km. Overall, the findings show a marked geographical concentration of patients around GGH, Yanam, with the largest proportion residing within 5 km and a general reduction in patient numbers with increasing distance. This pattern suggests that geographical proximity may influence healthcare utilization and that patients from more distant areas were comparatively less represented in the study population. **Figure 1** displays a spatial distribution map generated from a Geographic Information System (GIS) tool, QGIS. It maps patient distribution relative to a central point using a concentric-ring (buffer-zone) layout and directional axes, with GGH placed over localized satellite imagery as the origin point (0 km). The vast majority of the study population resided in close proximity to the hospital, with 59.60% (n = 6,139) clustered within a <5 km radius. Population density tapered off as distance increased, with 17.39% (n = 1,791) located between 6-15 km, 16.81% (n = 1,731) within 16-25 km and less than 3% distributed across the farther peripheral bands beyond 25 km. In terms of direction, the East sector accommodated nearly half of the sample (49.10%, n = 5,057) across 56 catchments and the West sector represented the second largest group (26.73%, n = 2,753) over 23 locations, with a notable cluster in the 16-25 km band (14.46%, n = 1,489). The South and North vectors accounted for 13.69% (n = 1,410) and 10.49% (n = 1,080) respectively, confirming that the core patient base is strongly centre in the immediate urban and peri-urban coastal sectors flanking the hospital.

Table 1: Demographic profile of the study population by age and gender distribution (N = 10,300)

Category	Subgroup	N (%)
Age of the patients	<15 years	837 (8.14%)
	16-30 years	2192 (21.28%)
	31-45 years	3097 (30.06%)
Gender of the patients	46-60 years	2129 (20.67%)
	>60 years	2045 (19.85%)
	Male child	895 (8.69%)
	Female child	1200 (11.65%)
	Adult male	4117 (39.97%)
	Adult female	4088 (39.69%)

Table 2: Distribution of dental treatment modalities availed by the patient population (N = 10,300)

Treatment availed by the patients	N (%)
Oral prophylaxis (scaling)	1335 (12.96%)
Extraction	6403 (62.17%)
Restoration	1316 (12.78%)
Root canal treatment	455 (4.42%)
Prosthesis	340 (3.30%)
Biopsy	111 (1.08%)
Others (trauma cases, management of facial pain, suturing of lacerated wounds)	340 (3.30%)

Table 3: Geographical distribution of the study population by distance and direction from the hub (GGH, Yanam) (N = 10,300)

Distance (km)	North of GGH	South of GGH	East of GGH	West of GGH
<5 km	0 - 0 (0.00%)	9 loc - 720 (6.99%)	54 loc - 4826 (46.85%)	6 loc - 593 (5.76%)
6-15 km	6 loc - 981 (9.52%)	1 loc - 64 (0.62%)	2 loc - 231 (2.24%)	3 loc - 515 (5.00%)
16-25 km	1 loc - 54 (0.52%)	2 loc - 188 (1.82%)	0 - 0 (0.00%)	11 loc - 1489 (14.46%)
26-35 km	0 - 0 (0.00%)	13 loc - 400 (3.88%)	0 - 0 (0.00%)	2 loc - 100 (0.97%)
36-45 km	0 - 0 (0.00%)	1 loc - 38 (0.37%)	0 - 0 (0.00%)	0 - 0 (0.00%)
>45 km	1 loc - 45 (0.46%)	0 - 0 (0.00%)	0 - 0 (0.00%)	1 loc - 56 (0.54%)
Total	8 loc - 1080 (10.49%)	26 loc - 1410 (13.69%)	56 loc - 5057 (49.09%)	23 loc - 2753 (26.73%)

loc, number of distinct locations mapped within the band

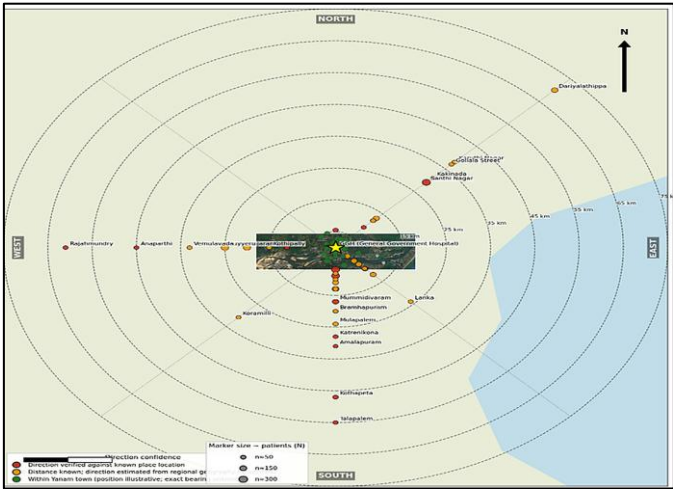


Figure 1: Geospatial mapping of the distribution of locations around Government General Hospital (GGH), Yanam

Discussion:

The present study showed that geographic proximity remains a major determinant of dental service utilization at Government General Hospital (GGH), Yanam. Nearly three-fifths of the study population (59.60%) resided within 5 km of the hospital, while patient attendance declined progressively with increasing distance, illustrating the well-recognized distance-decay phenomenon. This finding indicates that individuals living closer to the hospital experience fewer travel-related barriers and are therefore more likely to seek timely dental care. Similar observations were reported by significant geographical inequalities in access to National Health Service dental practices across Scotland, Northern Ireland and Wales, with remote populations experiencing substantially reduced accessibility

despite adequate urban workforce density. In a coastal Indian setting, Pandey *et al.* [5] further showed that natural geographic barriers, including rivers and coastal transit limitations, significantly increase travel impedance and reduce utilization of dental services. Using GIS-based spatial analysis, Nayak *et al.* [8] also confirmed that reduced travel distance improves access to routine dental care, whereas increasing spatial impedance discourages regular healthcare utilization. The present study additionally identified considerable patient inflow from western regions extending toward the Andhra Pradesh border, with 14.46% of patients traveling from distances of 16-25 km. This finding emphasizes the importance of GGH, Yanam, as a referral center serving surrounding rural and peri-urban communities where affordable dental infrastructure is limited. Similar regional disparities were observed by Okumu *et al.* [9], who showed severe rural-urban inequalities, in Kenya, where urban centers possessed the majority of the dental workforce while remote counties lacked functional dental facilities. Comparable findings were reported by Singh *et al.* [10], who observed that most patients attending a government dental center in a Tier II Indian city originated from nearby areas, confirming that utilization declines with increasing distance. Likewise, Rajput *et al.* [11] showed that individuals residing close to a dental facility were significantly more likely to utilize oral healthcare services than those living farther away, emphasizing the influence of geographic accessibility on health-seeking behavior. The predominance of extractions (62.17%) observed in the present study indicates delayed presentation and a high burden of untreated oral diseases among patients attending the hospital. Individuals traveling from distant locations often seek care only when symptoms become severe, resulting in greater demand for emergency and definitive treatment. Similarly, Meeral and Arumugham [12] showed spatial clustering of patients attending a private dental institution, although utilization patterns in

private practice were influenced more strongly by socioeconomic status and affordability than in public-sector facilities. Finally, Pandya *et al.* [5] reported marked clustering of dental facilities within urban Jaipur, whereas surrounding rural regions experienced poor accessibility because of inadequate service distribution. Collectively, these findings support the integration of GIS-based planning into oral health policy to improve the equitable distribution of dental services, strengthen outreach programs for underserved populations and encourage preventive dental care while reducing dependence on extraction-based treatment.

Conclusion:

Geo-spatial analysis showed that dental service utilization at GGH, Yanam, declined markedly with increasing distance from the hospital. The predominance of extractions indicates a high burden of advanced dental disease and reliance on public facilities for symptomatic care. Geospatially targeted mobile dental services and community screening may improve equitable access and strengthen preventive oral healthcare.

Data availability statement:

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest: None.

Funding source: None

Ethical clearance:

Obtained from the institutional ethical committee, with respective permissions obtained to access the secondary data

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