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Association Between Spatial Accessibility of Oral Healthcare Services using Geo-Mapping and Oral Healthcare Services Utilization in a Geographic Area of Andhra Pradesh, India

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Abstract

Objective: The study aimed to assess the relationship between spatial accessibility of oral healthcare facilities and dental service utilization rates in a geographic area of Andhra Pradesh, India.

Methods: This cross-sectional study was conducted in one urban (administrative wards) and two rural areas in West Godavari district of Coastal Andhra Pradesh, India. All private, public and dental care settings of teaching institutions located within the 20 km radius were plotted using Google's open street map. Arc GIS Pro software was used for attribute analysis and determining buffer zones. 520 per each area, together 1560 individuals were selected through stratified cluster random sampling to measure annual dental service utilization rates. Chi-square test and Fisher's exact tests were used for bivariate analysis and binary logistic regression analysis to assess the predictors of dental service utilization.

Results: In this study out of 1560 individual contacted, 1507 agreed to participate. Forty-nine oral healthcare centers were geo-tagged. Availability of dental services within 15 minutes of travel time [odds= 4.64; P=0.000] and located within 6-10 km distance from the patient's residence [odds= 3.22; P=0.002] were the two significant factors associated with oral healthcare service utilization rates.

Conclusion: There is an uneven distribution of oral healthcare facilities which reflects on the utilization rates. A measure to reduce the urban-rural gap in spatial distribution is essential to enhance the dental service utilization rates.

Keywords: Dental services, Geo-mapping, Dentists, India.

Introduction

Dental service utilization is a complex issue and it is influenced by variety of factors [1]. A meta-analysis conducted by Talukdar R et al. [1] reported that the pooled estimate of dental service utilization rates in India was 23.96% and a study conducted by Pradeep Y et al. [2] in the population of Krishna district, Andhra Pradesh reported that annual dental service utilization rate was 27.6% and there is a gap between need, demand and effective demand in dental care. Research indicates that multiple factors like treatment cost, lack of perceived need for care, accessibility, education level, distance, waiting time, etc., can impact the general population's utilization of oral health services. These barriers to access and low utilization of dental care not only affect individuals and communities but also pose a significant public health challenge to any country [1].

Various studies reported from India about the factors influencing utilization and non- utilization of oral healthcare services. A study conducted by Tharshini P et al. [3] about factors influencing dental service seeking behaviours in a sample of population from Chennai, India identified accommodation (54.8%) is the major barrier in seeking dental care and 5.6% of them reported accessibility as a barrier. Another study

conducted by Jadhav SK et al. [4] to identify the patterns and barriers in dental service utilization in primary health centers in Haryana, India reported that people's proximity to dental care centers, especially staying within 5 km radius was one of the facilitation factors for dental service utilization.

Dental care delivery system in India mostly comprises of private dental clinics, dental institutions and dental wings of public/government hospitals. Among these, private dental clinics contribute nearly 80% of the dental care and there is no state sponsored/supported dental insurance for common public [5]. Dental education and availability of number of dentists in India have been increased drastically in last two decades. The number of dental colleges has increased from three dental colleges at the time of independence to 323 and currently more than 3.5 lakh dentists were registered in India. The dentist population ratio is around 1:5000 which is lesser than WHO recommended dentists population ratio 1:7500 [6].

However, there is an enormous growth in manpower and oral healthcare facilities, urban localities witnessed most of this growth compared to the rural areas [7]. It is important to assess the spatial distribution of dental care facilities for future planning and development of government policies towards equitable distribution of services.

Geographic Information Systems (GIS) utilizes information linked to a specific location (geo-referencing) in order to generate a multi-layered map displaying distinct characteristics that can be overlaid [8]. GIS enables the creation and analysis of maps to help develop more targeted healthcare strategies. Visual representation of statistical information is clearer and simpler to understand than other types of data representation [8]. Density maps help in identifying concentration of healthcare centers, patients, risk factors, vectors, etc. and Kernel density measures the density of features in a specific area and surrounding features, per unit area, in a pixelated format [9]. Various studies have been reported in the literature about utilization of GIS in assessing healthcare accessibility [10,11].

Geo-mapping of the oral healthcare facilities will help in scientific way of assessing the spatial availability of oral healthcare services [9]. Few states in India like Uttar Pradesh is already using GIS to locate and asses the accessibility of government healthcare centers [12]. GIS has several uses in healthcare delivery system and to name few- it helps in planning healthcare services and also helps in disease/health problem surveillance. For example, a study reported by Ali NIM et al. [13] about spatial distribution of public dental healthcare facilities for school children in Malaysia highlighted the inequalities in availability of services and these findings guide in prioritizing the dental health resources.

Only one study reported about distribution of dental services in India, a study conducted by Pramod Nayak P et al. [9] assessed the accessibility of oral healthcare services in three coastal Karnataka districts, India using GIS has reported that uneven urban/rural distribution of dental services with more concentration of dental care facilities in urban and high-income areas. However, this study highlighted inequality in distribution of dental clinics; it did not relate dental service utilization rates with accessibility of services.

Andhra Pradesh is a Southern state of India, located in east coast with population around 54 million. Nearly 30% were urban residents and rest belonged to rural areas [14]. The number of registered dentists in Andhra Pradesh was 27781 [15].

There were isolated studies in the literature reporting either dental service utilization rates or number of oral healthcare facilities in India [1,2], but there was no research to correlate the spatial accessibility of oral healthcare services in terms of distance via road network to dental service utilization rates.

This research gap warrants an investigation into geographical accessibility of oral healthcare services in Andhra Pradesh for future recommendations on oral healthcare delivery, such as mobile dental delivery systems or even beginning of new oral healthcare facilities in underserved areas. Furthermore, the findings will serve as a guideline for future research. So, this study was conducted with the aim of assessing the relationship between spatial availability of oral healthcare facilities in terms of distance (in km) and time required to travel though road network and dental service utilization rates in Andhra Pradesh, India.

Materials and Methods

Study design

This cross-sectional study was conducted to assess the association between spatial accessibility of oral healthcare services and oral healthcare services utilization rates in a sample of two different geographic areas of Coastal Andhra Pradesh. Data was collected between February 2024 to March 2024.Ethical approval for this study protocol was obtained from Scientific Review Board of Saveetha Dental colleges and Hospitals, India [SRB/SDC/PhD/PHD-2324/23/TH-099]. Written informed consent was taken from individual participants prior to data collection. The present study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Study settings and participants

This research was conducted in one urban and two rural areas (administrative wards) of Tadepalligudem mandal in West Godavari district of Coastal Andhra Pradesh, India **[Figure-1].** West Godavari district is one

of the most prosperous districts due to its fertile agricultural lands and water resources. The study area lies on the latitude and Longitudes of 16.80° N, 81.53° E [16].

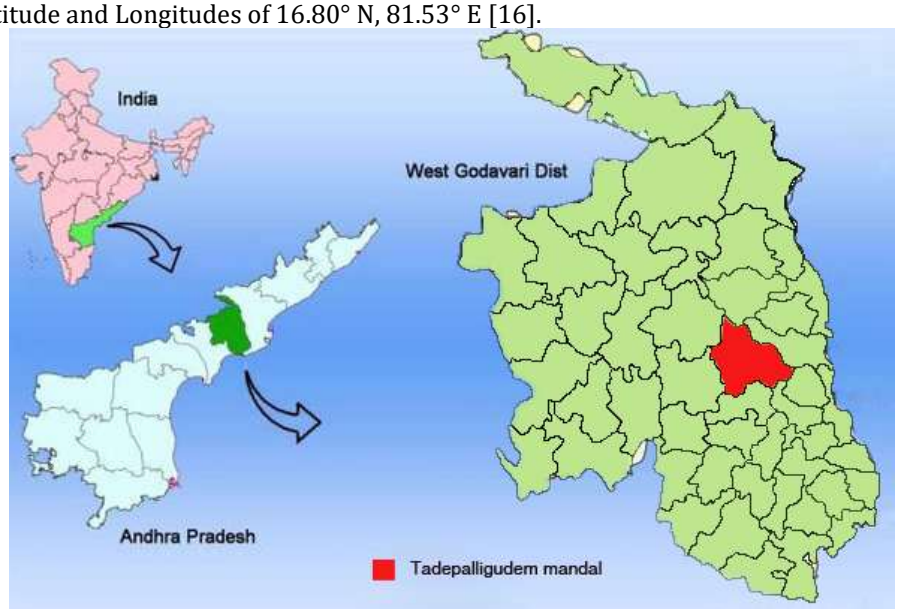

Figure 1. Location map of selected study map

Sample size calculation

Sample size was calculated based on the dental care utilization rates reported from pervious study [2]. Four hundred and seventy per each cluster was found to be sufficient to detect statistically significant difference of 10% in dental care utilization rates with 95% Confidence Interval and 80% power. Assuming 10-20% of attrition, sample size was increased to 520 per each cluster. Therefore, final sample size was 520 per cluster and together 1560 individuals for 3 clusters.

A stratified cluster random sampling was used in this study- simple random sampling (lottery) method in the first three phases were used to select district, mandals and administrative wards and finally systematic random sampling method was used to select households (participants). The study area selected for this research was Tadepalligudem mandal which has total population of 192,162 individuals, among these 88,130 were in rural areas and 104,032 were urban population.

The urban location selected was Tadepalligudem town consists of 35 administrative wards, out which ward numbers 27 and 33 were selected and two rural areas out of 41 villages were included in this study- Kommugudem village with population of 5074 and Tadepalle village with population of 11081.

Geo-coding

All the private, public dental care centers and dental care settings of teaching institutions located within the 20 km radius to study areas were listed initially and geo-coding of these centers were done by plotting through Google's open street map which is a free access geo-coding website. Latitudes and longitudes of the locations of dental practices were entered in Microsoft Excel sheet initially; duplicate entries were corrected and later converted to Microsoft CSV file for data transfer. Geo-coding was completed using GIS software (Arc GIS Pro Version 3.4, ESRI, California, USA).

Parameters assessed

Oral health accessibility to the study participants was categorized based on the travel distance (through road) from their houses to the nearest dental care facility and the time required inn minutes) to reach the facility. These parameters were categorized based on the study reported by Jadhav SK et al. [4] which used ≤5, 6-10, and 11-20 km as buffer zones, and travel times of ≤15, 16-30, and 31-60 minutes were referenced from research conducted by Shubayr et al. [11] and Cho HA et al. [17].

Dental service utilization rates in this study were defined as the number of dental visits of an individual in last one year (annual dental service utilization rates).

Statistical analysis

Collected data was analysed using statistical software for social Sciences (IBM SPSS statistics version 22, License Authorization Wizard. Ink, Chicago, USA). Chi-square test and Fisher's exact tests were used for bivariate analysis. The key study variable - utilization of dental service was dichotomised into at least one dental visit per year or no dental visit in last one year duration and binary logistic regression analysis was conducted to assess the predictors of dentals service utilization. Variables which got $p<0.25$ in bivariate analysis were included in the regression model. P-values which were ≤0.05 was considered as statistically significant.

Results

Out of 49 oral healthcare facilities geo-tagged, 44 were located in urban areas and 5 were located in rural areas. Out of 1560 individuals approached to participate in this study from the three areas, 1507 agreed to participate in this study with response rate of 96.6%; Out of 1507 participants, 502 were from urban area, 491 were from Kommugudem village and 514 were from Tadepalle village **[Table 1].**

Table 1. Population distribution and location of oral healthcare centers of study area

Variable	Number
Population	
Urban: Tadepalligudem town- Ward numbers 27 and 34	13,546
Rural1: Kommugudem village	5070
Rural2: Tadepalle village	11081
Oral healthcare facilities	
Urban	44
Rural	05

Among the study participants 54.74% of them were males, 21.77% belonged to 18-25 years, 19.84% in 26-35 years, 17.72% in 36-45 years, 20.64% were in 46-60 years and 20.04% were in above 60-year age groups respectively. Nearly, one-fifth (20.57%) were illiterates and 4.51% of the completed professional education. Annual per capita income of 39.08% of the participants was less than fifty thousand rupees and 7.43 had per capita income more than 200,000 rupees **[Table 2].**

Table 2. Socio-demographic features of the study participants

Variable	Number(%)
Location	
Urban: Ward numbers 27 and 34	502(33.31)
Rural 1: Kommugudem village	491(32.58)
Rural 2: Tadepalle village	514(34.11)
TOTAL	1507
Gender	
Male	825(54.74)
Female	682(45.26)
Age group	
18-25 years	328(21.77)
26-35 years	299(19.84)
36-45 years	267(17.72)
46-60 years	311(20.64)
>60 years	302(20.04)
Education	
No education	310(20.57)
Primary school	414(27.47)
Middle school	104(6.91)
High school	227(15.06)
Inter or diploma	148(9.82)
Graduate	236(15.66)
Professional	68(4.51)
Per capita income(rupees)	
<50,000	589(39.08)
51-100000	403(26.74)
100001-150000	267(17.72)
150001-200000	136(9.02)
>200000	112(7.43)

Table 3 presents distribution of various oral healthcare centers in terms of road travelling distance to study area. A total of 45 oral healthcare centers located within 20 km radius to urban study participants; Out of 45, 18 were within 5 km radius, 3 were between 6-10 km and 24 were between 11-20 km radius. Among this 45, just only 3 were public centers, one centre was a satellite clinic run by a dental teaching institution and rest all were private centers **[Figure 2].** One of the rural study clusters, Kommugudem has no oral healthcare centers within 5 or 10 km radius and it has twenty oral healthcare centers between

11-20 km radius. Another rural cluster, Tadepalle village has 18 oral healthcare centers within 5 km radius, 2 were in 6-10 km radius and 4 were in 11-20 km radius.

Table 3. Distribution of oral healthcare centers in terms of distance to the study area

Study area	Type of dental care facility	≤5 km	6-10 km	11-20 km	Total	Chi-square / Fisher's test
Urban: Tadepalligudem town-Ward numbers 27 and 34	Private	17(41.46)	01(2.44)	23(56.10)	41	Test value = 4.03 P=0.252
	Public	01(33.33)	01(33.33)	01(33.33)	3	
	Dental college (satellite clinic)	0	01(100)	0	01	
	Total	18(40)	03(6.67)	24(53.33)	45	
Rural 1: Kommugudem village	Private	0	0	18(100)	18	Test value = 3.25 P=0.122
	Public	0	0	01(100)	01	
	Dental college	0	0	01(100)	01	
	Total	0	0	20(100)	20	
Rural 2: Tadepalle village	Private	17(77.27)	1(4.55)	4(18.18)	22	Test value = 3.73 P=0.221
	Public	1(100)	0		1	
	Dental college	0	1(100)	0	1	
	Total	18(75)	2(8.3)	4(16.7)	24	

Note: Dental health care centers are overlapping among study areas; For example, dental college centre is located within 5 km to urban participants and same facility is at 11-20 km vicinity to rural 1 participant.

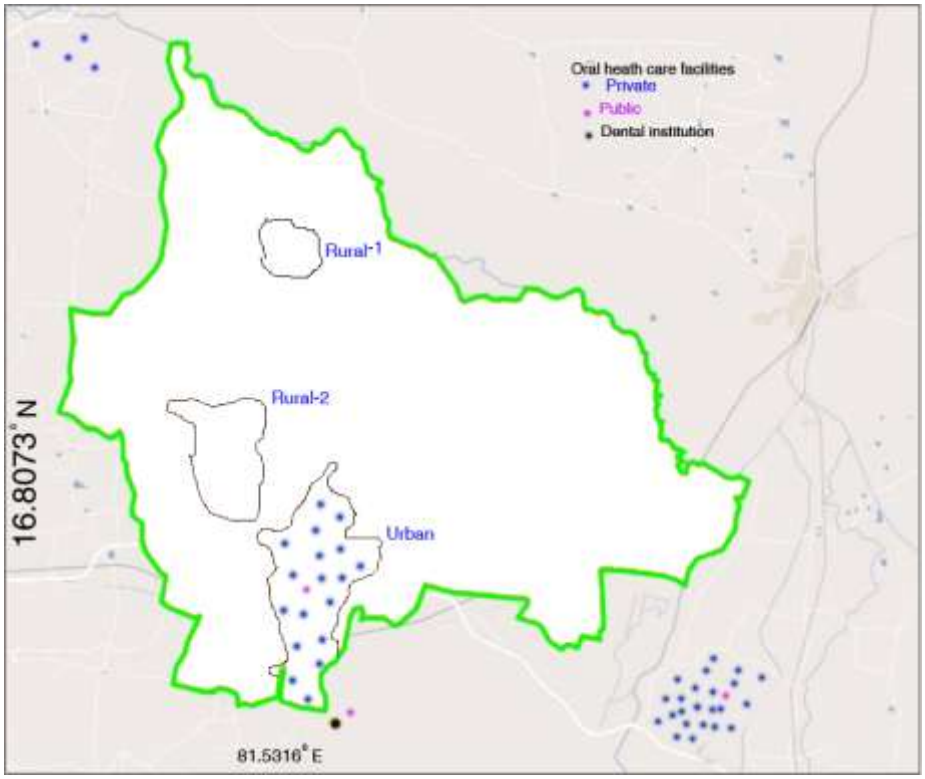

Figure 2. Geo-mapping of oral healthcare facilities in the study area

Forty percent of the oral healthcare centers in urban areas lies within 15 minutes travel time to the urban study participants, whereas one of the rural clusters (Kommugudem) has all centers between 3-60 minutes travel time and another rural cluster (Tadepalle) has more than half (56%) of the centers within 16-30 minutes travel time **[Table 4].**

Table 4. Distribution of oral healthcare centers in terms of travel time to study area

Study area	Type of dental care facility	≤15 mins	16-30 mins	31-60 mins	Total	Chi-square / Fisher's test
Urban: Tadepalligudem town-Ward numbers 27 and 34	Private	17(41.46)	01(2.44)	23(56.10)	41	Test value = 2.11 P= 0.714
	Public	01(33.33)	01(33.33)	01(33.33)	3	
	Dental college (satellite clinic)	0	01(100)	0	01	
	Total	18(40)	03(6.67)	24(53.33)	45	
Rural1: Kommugudem village	Private	0	0	18(100)	18	Test value =3.17 P=0.212
	Public	0	0	01(100)	01	
	Dental college	0	0	01(100)	01	
	Total	0	0	20(100)	20	
Rural 2: Tadepalle village	Private	6(27.27)	12(54.55)	4(18.18)	22	Test value = 2.78 P=0.332
	Public	0	1(100)	0	1	
	Dental college	0	1(100)	0	1	
	Total	6(24)	14(56)	5(20)	24	

Nearly 60% of the study participants did not visit oral healthcare services in last one year duration, 18.51% of them had one visit in last one year, 9.09% had 2 visits/year and 12.35% had more than 2 visits/year. Female participants had visited dental clinic more often than male counterparts, 15.11% of them has more than 2 visits/year against 10.06% in males which is statistically significant [P=0.0311]. No significant differences in number of dental visits across various sub categories of education, income and age group of the participants. **Table 5** presents dental service utilization rates in relation to socio-demographic features of the study participants.

Table 5. Comparison of dental service utilization rates with socio-demographic features

Variable	No dental visit in last one year	One visit/year	02 visits/year	More than 02 visits/year	Chi-square test
Area					
Urban	208(41.43)	121(24.10)	75(14.94)	98(19.53)	$\chi2$ =6.12 P=0.245
Rural 1	367(74.75)	61(12.42)	24(4.89)	39(7.94)	
Rural 2	330(64.20)	97(18.87)	38(7.40)	49(9.53)	
TOTAL	905(60.05)	279(18.51)	137(9.09)	186(12.35)	
Gender					
Male	517(62.67)	150(18.18)	75(9.09)	83(10.06)	$\chi2$ =4.72 P=0.0311
Female	388(56.89)	129(18.91)	62(9.09)	103(15.11)	
Age group					
18-25 years	187(57.01)	55(16.77)	27(8.23)	59(17.99)	$\chi2$ = 7.86 P=0.132
26-35 years	181(60.54)	52(17.39)	27(9.03)	39(13.04)	
36-45 years	160(59.93)	49(18.35)	25(9.36)	33(12.36)	
46-60 years	197(63.34)	57(18.33)	29(9.33)	28(9.00)	
>60 years	180(59.60)	66(21.85)	29(9.61)	27(8.94)	
Education					
No education	192(61.94)	62(20.00)	33(10.64)	23(7.42)	$\chi2$ = 2.68 P=0.326
Primary school	259(62.56)	81(19.57)	27(6.52)	47(11.35)	
Middle school	66(63.46)	19(18.27)	9(8.65)	10(9.62)	
High school	142(62.56)	27(11.89)	23(10.13)	35(15.42)	
Inter or diploma	89(60.54)	27(18.26)	13(8.88)	18(12.32)	
Graduate	142(60.27)	43(18.22)	21(8.92)	29(12.29)	
Professional	15(22.06)	20(29.41)	15(22.06)	18(26.47)	
Per capita income(rupees)					$\chi2$ = 6.28 P=0.138

<50,000	377(64.01)	103(17.48)	42(7.13)	67(11.38)	
51-100000	263(65.26)	80(19.85)	20(4.96)	40(9.93)	
100001-150000	164(61.42)	56(20.97)	16(5.99)	31(11.62)	
150001-200000	65(47.79)	21(15.44)	22(16.18)	28(20.59)	
>200000	36(32.14)	19(16.96)	37(33.04)	20(17.86)	

Highest utilization rates were associated with the dental clinics located within 6-10 km radius and travel time within 15 minutes which was statistically significant. Most of the dental visits i.e. 71% of 1 visit/year, 60.06% of 2 visits/year and 76.35% of more than 2 visits/year were to private clinics. Dental service utilization rates were compared with spatial accessibility of services in **Table 6.**

Table 6. Comparison of dental service utilization rates with spatial accessibility of services

Variable	1 Visit/year (n=279)	2 Visit/year (n=137)	>2 Visit/year (n=186)	Chi-square test
Distance				
≤5 km	68(24.40)	28(20.40)	36(19.30)	$\chi2 = 10.78$
6-10 km	151(54.10)	79(57.67)	116(62.33)	P=0.022
11-20 km	60(21.45)	30(21.90)	34(18.45)	
Time				
≤15 mins	142(50.90)	65(47.40)	98(52.70)	$\chi2 =21.55$
16-30 mins	83(29.66)	41(29.94)	50(26.90)	P=0.000
31-60 mins	54(19.45)	32(22.65)	38(20.40)	
Type of clinic				
Private	198(71.00)	83(60.60)	142(76.30)	$\chi2 = 3.11$
Public	21(7.53)	17(12.40)	18(9.67)	P=0.632
Dental college	60(21.50)	37(27.00)	26(14.00)	

Among the factors included in the model, availability of dental services within 15 minutes of travel time [odds=4.64; P=0.000] and located within 6-10 km distance from the patient's residence [odds=3.22; P=0.002] were the two significant factors associated with oral healthcare service utilization of the study participants. **Table 7** presents the logistic regression analysis for the predictors of dental service utilization.

Table 7. Binary logistic regression analysis for predictors of utilization of dental care

Variable	Adjusted odds ratio	95% confidence intervals	P-value
Area			
Urban	1.00 (ref)	-	-
Rural1	0.89	0.64, 1.12	0.184
Rural2	1.36	0.97, 1.58	0.462
Age			
18-25 years	1.00 (ref)	-	-
26-35 years	1.24	0.92, 1.43	0.084
36-45 years	0.89	0.84, 1.22	0.142
46-60 years	1.18	0.90, 1.39	0.524
>60 years	1.05	0.83, 1.46	0.098
Gender			
Male	1.00 (ref)	-	-
Female	1.02	0.88, 1.67	0.246
Education			
Professional	1.00 (ref)	-	
Graduate	1.28	0.96, 1.44	0.074
Inter or diploma	1.13	0.92, 1.45	0.244
High school	0.96	0.86, 1.42	0.064
Middle school	1.10	0.91, 1.39	0.432
Primary school	1.34	0.98, 1.42	0.726
No education	1.06	0.70, 1.25	0.222
Per capita income(rupees)			
>200000			
150001-200000	1.00 (ref)	-	-
100001-150000	1.26	0.88, 1.35	0.482

51-100000	0.89	0.78, 1.26	0.084
<50,000	1.22	0.90, 1.30	0.381
	1.00	0.93, 1.26	0.278
Distance (in km)			
11-20	1.00 (ref)	-	-
6-10	3.22*	1.06, 4.33	0.002
≤5	1.18	0.80, 1.28	0.488
Time (in minutes)			
31-60	1.00(ref)	-	-
16-30	1.28	0.92, 1.34	0.076
≤15	4.64*	1.48, 6.02	0.000

Discussion

This study examined the influence of spatial distribution of oral healthcare services using GIS-based methods on the utilizations of dental services in one urban and two rural areas of coastal Andhra Pradesh, India. This is the first study reporting the spatial availability of oral healthcare services to utilization rates in India. This research finding may contribute for the policy making and planning dental services in consideration to geographic distribution in this region. The key findings of this research support the hypothesis that spatial availability of services will positively contribute for dental service utilization. Nonetheless, the research also revealed that uneven distribution of oral healthcare services .i.e. mainly concentrated in the urban areas. Out of 49 oral healthcare facilities geo-tagged in the study area, 44 facilities were located in the urban areas; moreover, majority of the settings was private, just 3 public centers and one clinic was a satellite clinic run by a dental institution. This urban-rural mal distribution of the dental care services was similar to the findings of the study reported by Pramod Nayak P et al. [9], in which the authors reported about spatial distribution of dental clinic in coastal districts of Karnataka. Eighty-five dental clinics out of 340 in their study were in rural areas and 255 were in urban areas. Within the India, there were differences in dental work force distribution, certain states like Karnataka, Andhra Pradesh, Tamilnadu, etc. has more than required dental work force and states like Jharkhand and Uttaranchal has least dental work force [18].

Similar findings were reported by various studies across the world [19, 20, 21]. Various factors contribute for this mal-distribution of dentists, a study reported by Hashimura T et al. [22] from Japan identified that there were 273 dentists per 100000 people in the areas which has dental school and whereas in other areas 59-60 dentists per 100000 people. Another study conducted by Jean G et al. [23] from Australia reported that inequalities in the distribution of dentists were related to the socio-economic profiles of the population in that particular geographic area, as more dentists tends to open up their dental practices in areas with high socio-economic profile. This unequal distribution of dental clinics suggests that some people in rural areas may not get preventive care and prompt treatment for their dental problems, which could not only negatively affect their oral health status but also leads to increased demand for emergency dental care [24]. Enhancing the spread ofdental clinics is essential for providing easy access to dental services. Although, most of the dental clinics were located within 5 km and 6-10 km category in urban areas, a small number were located beyond 10 km distance, which created hurdles for rural population in accessing dental services.

The dental care service utilization patterns in this study suggest that 18.51% visited dentists once in last on year, 9.09% them visited twice, 12.35% of them had more than two visits per year and 60.5% of them did not visit dentist in last one year duration. Dental care service utilization rates in this study were higher than those reported by various studies [1,2]. Dental service utilization rates of our study were close to the study reported by MRV Siluvai S et al. [25] in which authors reported that dental service utilization rates as 37.8% in rural areas of Chengalpattu, Tamilnadu, and lack of awareness was one of the key barriers for accessing dental services. In our study, dental service utilization rates were higher in the females than the males and also proportion of people who had more than two dental visits per year were also more the females [15.11% versus 10.06%], which is statistically significant [P=0.03]. These findings were similar to the study reported by Kailembo A et al. [26] that unmet dental needs in the males were more than female counterparts and our findings were in contrast to the study reported by Shah N [27], that dental service utilization was more in the males compared to the females in their study. Logistic regression model used in our study identified statistically significant association between dental service utilization with spatial accessibility of the oral healthcare services. People who had dental services access within 15 minutes of journey from their residences had utilized 4.64 times more than others[P=0.000] and also people who stayed 6-10 km away from dental services utilized dental services more than others [odds=3.22; P=0.002]. One of the key findings of this study, people tend to access dental services which require less time to travel was similar to the study reported by Nagdev P et al. [28] that time required to reach dental clinic was one

of the barriers in seeking dental care along with other socio-economic factors. Maximum oral healthcare service utilization patterns were observed in the people who had access to care at a distance between 6-10 km, which is similar to the study reported by Shin et al. [29] that people tend to bypass the clinics present in immediate neighbourhoods and prefer to travel some distance, 58.9% of the patients in their study travelled a median distance of 8.4 km to get dental treatment done. This pattern of dental service utilization can be attributed to the type of dental service utilized and socio-economic status of the patients [17,30] and people from lowest income quartile tend to travel more distance to seek dental care than others [17]. Another possible explanation for maximum dental service utilization bet > 15 km and 6-10 km groups were distance vs travel time may not be always directly proportional and traffic congestion in urban areas may have confounding effect. Previous studies have highlighted that poor spatial access to the dental services has been related to the high prevalence of dental diseases [31] and poor quality of dental care [32]. Huang Z et al. [31] conducted a study on GIS based spatial accessibility of dental services and dental caries in Japanese children and this study concluded that mean dmft scores were directly proportional to the distance of dental care settings [31]. A study conducted in the Taiwan by Chung PC et al. [32] reported that spatial accessibility improved quality of dental care and patient satisfaction. High level of spatial accessibility of dentists also promotes increased tendency of using preventive dental care [odds=1.6, $P<0.05$] as reported by Yoon H et al. [33] in their study about preventive dental care utilization in the neighbourhoods of Austin, USA.

The present dental healthcare system in Andhra Pradesh needs to be revamped to address the mal distribution of dental care services. This requires proper integration between the dental health needs of the people in various areas, data about barriers and facilitators of dental care access and dental manpower planning. Union government of India has taken few initiatives to improve the spatial distribution of health services to rural areas in India such as allowing 100 percent foreign direct investments for setting up any healthcare facility in remote and rural areas [34] and also total tax exemption on the incomes of the hospitals or clinics operating the rural areas in India [35]. However, spatial accessibility is just one of the factors which influence dental service utilization, several studies reported lack of awareness regarding dental health [36,37] and perceived lack of need for the dental care [38,39] were also as major barriers for oral healthcare service utilization. To this end, initiatives to improve oral health awareness are required which will enable the people to utilize both preventive and curative dental care.

This study is the first to use GIS for spatial distribution of oral healthcare services and its relationship with oral healthcare service utilization in India. However, this study has few limitations which should be considered while interpreting the findings of the study. Firstly, we travelled across the whole study area by road, identified and geo-tagged all oral healthcare centers owned by qualified dentists and there is no comprehensive official list of oral healthcare centers available. Geo-tagged list of centers was confirmed once again with office bearers of local branch of Indian Dental Association to make sure we did not miss any facility. Secondly, we just listed number of oral healthcare centers and data about number of dental personnel, age, gender, their specialities and working hours were not recorded which may influence the patient's choices of seeking dental care. The types of dental facilities, the services offered (including hours of operation), the number of dentists and dental auxiliaries per facility, and the services offered by dental clinics in the area must all be examined in order to address these problems. Mapping the region's public, private, and other oral healthcare facilities, determining the population's dental health literacy, and estimating the prevalence of oral health problems would all be beneficial in order to substantiate these findings. These initiatives may not only contribute for the proper spatial distribution of oral healthcare services but also improve dental service utilization rates in the people.

Conclusion

The existing oral healthcare system in Andhra Pradesh is inadequate, urban concentration of dental practices may hinder the dental service utilization of the rural people. Our findings suggest that initiatives taken by the Union government of India to promote rural healthcare practices in the private sector could not bring much change in the spatial distribution of oral healthcare centers, and to compensate for this, priority should be given to rural areas in establishing any new public dental healthcare centers in the near future. Bridging the urban-rural gap in spatial distribution of oral healthcare services is essential to enhance the dental service utilization rates, which may further improve the oral health status of the people.

Declarations

Availability of data: Data will be made available upon request to the corresponding authors.

Competing interests: The authors declare that they have no conflicts of interest.

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