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Distribution of Adolescents with Gingivitis and Dental Calculus in Jequitinhonha Valley, State of Minas Gerais, South-Eastern Brazil: A Study Using Geoprocessing

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ABSTRACT

Periodontal disease studies in adolescents have shown considerable results. The aim of this study was to investigate the distribution of periodontal disease in adolescents living in Jequitinhonha Valley, State of Minas Gerais and South-Eastern Brazil.

Materials and Methods: Geoprocessing technology was used to elaborate quantitative and qualitative coropletic maps, in which it was possible to associate colour grading with Communitary Periodontal Index (CPI) variables drawn from a previous cross-sectional study (UFMG's Dentistry College, 2010). The study selected 13 cities of Jequitinhonha Valley, considering its population size and performance of oral health services. The survey was composed of 450 randomly selected adolescents ranging from 15 to 19 years, which were numbered considering both total and proportional teen population in each city. Data input was made on a graphic digital basis projecting the State area, using TerraView® computer software (4.2.1. version). Georeferencing of control points on the surface of the earth was made by the intersection of latitude and longitude coordinates (geocoding). Point and polygon vectorial model was used for data storage.

Results and Discussion: The incorporation of geographical concepts by public health studies is justified by the understanding of geographical space as the place where social transformations occur both as the deleterious effects on public health related to social inequalities. Map patterns were the mosaic type and may indicate that there is not a single source for the results found. The worst periodontal conditions found in adolescents were distributed throughout the region and concentrated in cities of greater population size and best oral health service performance. This fact can be associated with social, environmental, economic factors and also with oral health services management.

Conclusion: Georeferenced oral epidemiological studies may help to understand the role of environment in health outcome. The images formed from thematic maps provide subsidies for planning in oral health.

INTRODUCTION

Contemporary society experiences a new, rapidly evolving scientific-technological paradigm, which modifies the use of new computer technologies for the production and dissemination of knowledge and information on health, especially with the recognition of epidemiology as a science and articulation of health with other areas such as history, economics, politics, anthropology, sociology, geography and ecology, in the search for solutions to health hazards [1].

The incorporation of geographical concepts by public health studies is observed in the idea of geographic space as the place where social change occurs, as well as the deleterious effects on health of populations caused by social inequalities [1-4].

In 1768, physician James Lind published "An Essay on Diseases Incidental to European in Hot Climates", in which he attempted to link the distribution of diseases with specific geographic areas [5]. In the 19th century, John Snow used mapping techniques to analyze the cholera epidemic, which occurred in 1854 in the area of Soho, London [6]. Based on spatial distribution of cholera deaths, he demonstrated a spatial association between deaths and contaminated water sources distributed by different pumps for public supply, thus identifying the origin of epidemic.

Many technologies and techniques are used for the survey and manipulation of geographic information, among which stand out georeferencing and geoprocessing. In the late 90's and early 21st century, geoprocessing started to become a popular and socially-oriented methodology, being increasingly used in health as an important tool for planning, monitoring and evaluation of actions, policies and programs, besides contributing on the analysis of relationships between environment and health-related events, identifying regions and groups at high risk of disease, as well as in planning prevention and control of new or re-emerging diseases [7-15].

GIS (Geographic Information System) is a comprehensive system that combines several technologies for processing, handling, storage and presentation of spatial data by means of computational programs [16]. Involves knowledge on cartography, digital cartography, geography, statistics and computing [17-20].

Geoprocessing programs have as main feature the ability to manipulate graphical data (maps) and relate them to non-graphical data, i.e., each local–for example, city, district, neighbourhood (area), health center (point), avenue (line)–can be linked to a table with information from those – for example, number of cases occurring in some area, medical specialties in a health centre, bus routes that pass through an avenue [16,21,22].

The utilization of geographic space in oral health research was improved with access to computational cartographic tools. Its use is possible for data analysis based on the spatial distribution and geographic locations related on the oral health status of populations, as well as for planning and evaluation of actions, implementation of policies and strategies that might improve local health systems [23-27]. It also allows the elaboration of map models able to check and predict the occurrence and distribution of dental hazards in areas with specific spatial conditions [23-27].

Concerning health, spatial distribution refers to the use of quantitative methods in studies in which the object of interest is geographically defined, such as spatial distribution of occurrence of oral diseases and their relation to health services, in order to identify spatial patterns of morbidity or mortality and associated factors, describe diffusion processes of diseases, and generate knowledge about etiology, its prediction and control [3,4,12,16]. This fact is relevant to oral epidemiology because periodontal diseases have a high prevalence in populations of adolescents in Brazil and worldwide [28-30].

The application of geoprocessing to create coropletic maps for oral epidemiological research offers great possibilities, providing researchers with new ways to manage their information, thus becoming a powerful tool for connection between health and environment [2,9,24,31]. Recent studies have shown important results for planning oral health [14,23-27].

Geoprocessing can also be useful to evaluate dental care services by their distribution in areas or cities, type of service offered, and yet, by mean of programs to attract professionals to regions where demand is high, as well as evaluating access to dental care for individuals according to their ethnicity and socioeconomic status [11,12,27].

Due to limited resources in public health, there is increasingly a need for more efficient and resolute health programs. A key issue in this context refers to the implementation of an agile information system, which can identify areas and/or populations at risk, thus guiding interventions in health, including oral health. Geoprocessing is a new technology with potential for research in oral health in Brazil. The images generated from thematic maps of periodontal conditions help to understand spatial distribution of the disease and its possible social determination.

The aim of this study was to propose the elaboration of coropletic maps to describe the gingival condition of adolescents living in Jequitinhonha Valley based on the Community Periodontal Index (CPI), which is recommended by the World Health Organization 32, and where periodontal condition is evaluated in epidemiological studies by codes that vary between 0 (Healthy), 1 (Bleeding) and 2 (Calculus). Additionally, we used code 6 (Bleeding and Calculus) to register the presence of both conditions and not just the worst.

METHODOLOGY

The state of Minas Gerais is divided into 12 mesoregions. Jequitinhonha mesoregion comprises 52 municipalities with low socioeconomic development indexes 33 **(Figure 1)**.

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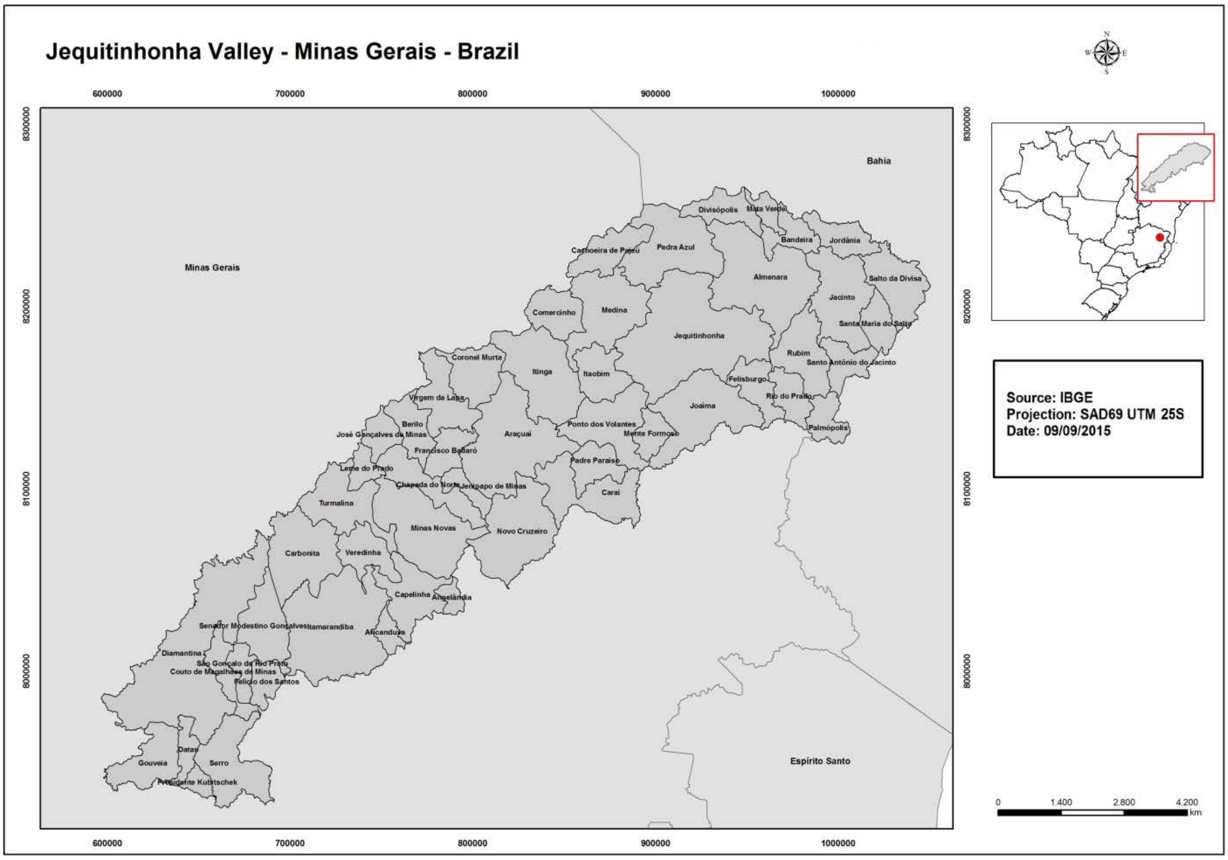

Figure 1. Geographical location of Jequitinhonha Valley, Brazil, 2015.

Municipality was used as the spatial unit because it is an administrative unit reference for primary data in health [5,18]. We used the South American Geodesic System (SAD 69) and Planimetric Datum Córrego Alegre, with projection on Universal Transverse of Mercator (UTM) with Zone 25S and numeric scale in Kilometers [5,18-20].

First it was built a database with attributive (non-graphic) data – or table – in Windows Excel ® program (2010 version), with numerical and categorical attributes/variables extracted from a cross-sectional study, conducted in 2010 and made available by UFMG's Dentistry College, containing data from 13 municipalities and 450 adolescents living in Jequitinhonha Valley, State of Minas Gerais [5,18].

The sampling plan by conglomerates was performed in two stages: 1 (municipalities) and 2 (individuals). To address the diversity among the municipalities, they were selected based on population size and performance of oral health services in each municipality. With these two variables, a 3×3 matrix was drawn, and municipalities listed at the main diagonal were included in the sample.

The 450 adolescents aged 15 to 19 years were randomly selected as the proportion of the population in the age group corresponding to each municipality and blocks drawn according to the Brazil Oral Health Manual - 2010 (SB Brasil) [28].

Then, graphical base was built with municipal geographically referenced alphanumeric data included in the study. The connection between the two bases was made by a common code or "primary key", which was the municipality's name [18,19]. Each information plan contains series of layers that represent a topic or class information, for example, CPI code (Healthy, Bleeding, Calculus, Bleeding and Calculus). Later, bases were projected on a digital graphic base of the State of Minas Gerais, made available by the Brazilian Institute of Geography and Statistics (IBGE) 33, using TerraView ® software (4.2.1 version) provided by the National Institute for Space Research (INPE).

Through the coordinate system, we performed the georeferencing of control points on Earth's surface at the intersection of latitude and longitude (positioning) [7,8,15,29]. This process, named geocoding, is the one by which the relationship between graphical and non-graphical bases is established [7,15]. The result of geocoding and intersection between graphical and non-graphical information or any spatial analysis, are coropletic maps [5,18,31]. For data storage, point and polygon vectorial model was used.

Quantitative and qualitative coropletic maps were elaborated, associating colour grading (from weakest to strongest) with area (from the smallest to the largest). Legend classification was also patterned in a maximum of five extracts with quantiles intervals [18,31,32]. A coropletic map can generate different spatial patterns depending on the type of information that will be inserted in the map legend [31]. The scale and object selected are important choices to map design and visual results [7].

RESULTS

Regarding CPI Index, **Table 1** shows that the 450 adolescents examined were 16 (3.5%) code 0 (Healthy), 232 (51.5%) code 1 (Bleeding), 38 (8.44%) code 2 (Calculus) and 164 (36.44%) code 6 (Bleeding and Calculus). Among the participating municipalities, 8 (61.53%) had individuals with code 0 (Healthy), 13 (100%) code 1 (Bleeding), 8 (61.53%) code 2 (Calculus) and 13 (100 %) code 6 (Bleeding and Calculus).

Table 1. Spatial distribution of adolescents according to CPI Index, Jequitinhonha Valley, Brazil, 2015.

Cities	CPI Index				Total
	Healthy	G. Bleeding	D.Calculus	Bleeding+Calculus	
Felisburgo	0	6	1	9	16
Gouveia	0	23	0	5	28
Itamarandiba	6	40	13	19	78
J.de Minas	2	8	0	8	18
Jacinto	2	14	4	7	27
Jequitinhonha	1	24	2	18	45
Palmópolis	1	12	0	4	17
Pedra Azul	0	18	7	31	56
Salto da Divisa	1	9	0	7	17
Serro	0	20	4	26	50
St. Ato Jacinto	1	13	0	8	22
Turmalina	0	28	4	11	43
V. da Lapa	2	17	3	11	33
Total	16	232	38	164	450

A total of 31 (6.88%) adolescents have never been to the dentist, and the municipalities of Turmalina and Serro were those who had the greatest number of individuals, 5 (16.12%). Recent toothache was present in 112 (24.88%) adolescents.

242 (53.78%) adolescents are female, 283 (62.89%) working activity, 112 (24.89%) sixteen years old, 284 (63.12%) brown skin color, 264 (58.67%) high school, 236 (52.44%) household income ranges from one and three minimum wages **(Table 2)**.

Table 2. Characteristics of adolescents of the study, Jequitinhonha Valley, Brazil, 2015.

Variables	N (%)
Gender	
Male	208 (46.22)
Female	242 (53.78)
Work Activity	
Yes	167 (37.11)
No	283 (62.89)
Age in Years	
15	108 (24)
16	112 (24.89)
17	86 (19.11)
18	75 (16.67)
19	69 (15.33)
Self-Reported Skin Color	
White	56 (12.44)
Black	49(10.88)
Yellow	17 (3.77)
Mixed/Brown	284 (63.12)
Indigenous	11 (2.44)
Not Answered	33 (7.34)
Schooling	
Elementary School	169 (37.55)
High School	264 (58.67)
College	17 (3.78)

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Household Incomes**	
Minimum Wage	160 (35.55)
1 to 3 Wages	236 (52.44)
Greater Than 3 wages	43 (9.56)
Not Answered	11 (2.45)
*Brazilian minimum wage in 2010=R$ 510,00 (USD=298.24). value of the USD=1.71	
**Economic Classification Criteria Standard – CritérioBrasil 2008	

Considering the five municipalities that did not have any individual with code 0 (Healthy), three are located in better performance and larger populations extract (Pedra Azul, Turmalina and Serro). The absence of individuals with code 0 was observed in all three categories of cities from the sampling plan **(Figure 2)**.

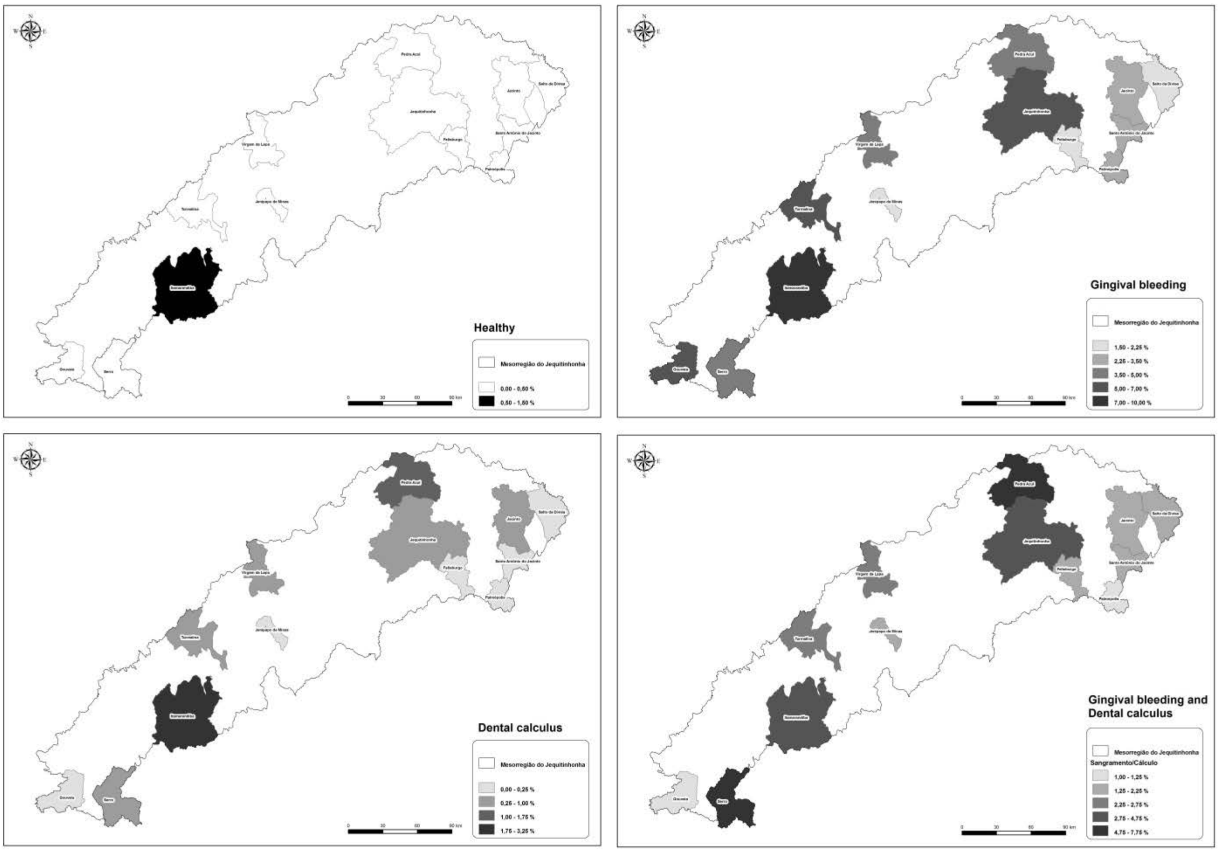

Figure 2. Distribution of adolescents living in Jequitinhonha Valley according to CPI Index, Brazil, 2015.

There was a concentration for code 1 (Bleeding) in four cities with better service performance and population size (Itamarandiba, Jequitinhonha, Serro and Turmalina), and in a city with medium-sized population and service performance (Gouveia) **(Figure 2)**.

Code 2 (Calculus) was more concentrated in the municipalities of better performance and population size (Itamarandiba and Pedra Azul), as well as concerning code 6 (Bleeding and Calculus) **(Figure 2)**.

DISCUSSION

The way the territory is occupied and used may reflect life conditions and oral health of populations. Historical and social construction process of Brazilian territory produced inequities in health [1-3,23]. Georeferenced oral epidemiological studies may help to understand how these inequalities were formed and how to deconstruct them [3,23,25]. The socially-constructed environment is no longer backdrop of the disease process of population [2,3,7,9,16,23]. Oral epidemiology needs to incorporate "social space" into the dynamics of disease process of communities and populations [3,4,12,16]. Each 'social space' has a reality, problems, demands and the mechanisms by which individuals and communities organize to achieve oral health.

Individuals with similar social profiles (income, education, work, sex, age group) may provide different levels of oral health depending on their individual attributes and also territorial housing, the places they travel, work and relationships established in living territory [1,4,28-30]. Our study corroborates this assertion.

Analysis on diseases distribution is done using three dimensions: person, time, space [4,16]. The use of study models that address the role of environment in health outcome brings more consistency and reliability to epidemiological findings [4]. Moreover, the complexity in relating social factors to oral problems requires increasingly careful analyses and measures, and also the use of numerous tools, to clearly explain the health-disease process in different populations. The identification of regions with different concentrations of fluoride naturally present in water has shown impacts over the prevalence and severity of dental caries, highlighting the environmental influence on population's oral health [14,23-26]. Because this was a cross sectional study, it was not possible to analyze periodontal health-disease process in adolescents living in Jequitinhonha Valley. This would require the completion of a longitudinal study. The worse periodontal conditions of adolescents were distributed throughout the Jequitinhonha region and concentrated in municipalities with larger populations and better service performance. This fact can be associated with local economic, environmental and social factors.

Individuals, communities and populations are at risk, individually and collectively, depending on age, sex, educational level, socioeconomic status or geographic location [18,23,28,29]. That is, research in oral health needs to consider social, collective and spatial dimensions for understanding health-disease process and disease behaviors in studied populations [2,4,9,26]. The distribution of oral health services also uses geographical issues such as territory, district planning and decentralization of the Brazilian Unified Health System (SUS) [5,11,14,18,27].

The main limitations to the use of geoprocessing in oral health are a lack of databases with geographic information, georeferenced cartographic databases, continuous qualification and training of human resources for their use and the high cost of programs [1,4,19]. Our study did not present these limitations, because the bases and the program were freely available for using. Alternative for qualification is outsourcing the making of maps, but it was not the case in our study. However, the current situation of scientific and technological development allows the use of geoprocessing tools for spatial approaches in oral health and promotes the improvement of oral epidemiological research in Brazil [4].

One way to solve problems on analysis of spatial information involves the development and use of maps, although its production process is complex, especially considering aspects of field data collection, storage and updating.

Our study proposes a discussion on the use of geoprocessing technology for mapping to support epidemiological studies and management of oral health. Coropletic maps are images and forms of health communication that can be used to enhance the interpretation of results of oral epidemiological research [24,25,31]. By locating populations and individuals with greater demand for dental services, it's possible to tailor financial, material and human resources as the local and regional specifics. Besides, they can help the management planning of oral health in decision making and corrective or preventive monitoring spatiotemporal aggravations as caries, oral cancer, fluorosis [24-26]. Our study confirms previous studies and adds the possibility of using coropletic maps for periodontal epidemiological studies.

Coropletic maps produced with geoprocessing technology also allow constant data updates, manipulation and analysis of gathered information [10,11]. However, they contain specific qualitative and quantitative information that characterizes an event or condition occurred in a specific territory, therefore allowing an analysis until a certain level, and requiring other approaches in subsequent studies [5,14,17].

Map patterns were mosaic-like and may indicate that there is a unique source for the results, and that, in this case, may be related to poverty [18]. However, care must be taken not to confuse results with a random fluctuation due to municipalities samples [18]. It's possible to control this effect by aggregating data or spatial statistical analysis, for greater stability [18-20].

One of the usual problems is to georeference health data, i.e., to get information about where one case happened and how to locate it on the map. There are several strategies to solve this: if a well-detailed map is available, containing the grid of streets, localities of the city and numbering blocks, the software itself allows the location of the health event. This occurs due to the limitations of information health systems.

Cartographic data type will depend on what is intended with the project, and the covered territory. Many information is important, such as location of health units and other urban equipment (schools, parks); urban infrastructure services (represented by lines: public systems of water supply and sewage, traffic routes, bus lines) and morphology of environment. Periodontal condition may be related to oral health service management because municipalities with better service performance and population size showed the worst results.

Georeferencing data on oral health is important for the interpretation of epidemiological studies, especially when they are related to population's socioeconomic profile and permit location of cases according to its distribution in a given geographical area [2,15,16,26,33]. It is also possible to analyze spatial data on oral health [21,23], in order to provide appropriate tools that allow municipal managers to implement strategic planning of oral health in the territories over which they have responsibility.

However, georeferencing of epidemiological data does not establish causal associations, but allows the characterization of studied objects and the identification of socioeconomic and environmental situations that potentially promote the occurrence of health events [8].

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CONCLUSION

Geoprocessing is a computational environment for exploring data, test hypotheses and generate new data and hypotheses as to identify areas and conditions under risk. It is possible to use tools for mapping georeferencing oral conditions both for surveillance services in oral health as for scientific research, in addition being accurate, fast and support-given for decision making in healthcare, mainly in epidemics.

By linking up with epidemiology, geoprocessing increases the possibilities of a better description, spatial analysis of diseases in large geographically referenced datasets. The ability to run multiple queries about a dataset, along with the use of high graphical resolution, has greatly facilitated the obtaining and interpretation of information on oral health. This fact permits to identify the most vulnerable areas, adverse events and case monitoring, and the election of surveillance indicators in oral health.

Coropletic maps of periodontal condition are an effective strategy to describe the situation of health and disease in adolescents. This facilitates the understanding and dissemination of information resulting from epidemiological research, and provides information for planning remedial actions.

Importantly, the potential use of geoprocessing in health should be characterized by multidisciplinarity. Computational resources and the power of communication via computer may even become facilitating agents to target this ideal. Unfortunately, cross-sector, institutional integration processes in health is still incipient in our country.

The elaboration of coropletic maps is not only a health's task. Maps in digital format must be obtained, and this certainly concerns to municipal or state planning staff. Before its completion, you must assemble a database, and each software requires a program or a prior standardization, so that data can be recognized by the system.

Storage, retrieval, search, handling, shipping, receiving, copying and display of information can be done manually, but this way leads those activities to become very slow, tedious, and difficult to standardize, with higher probability of errors occurring. Furthermore, paper maps are difficult to handle, store, send, receive and copy. Thus, the use of computers with computational geoprocessing programs makes those operations easier and more productive.

Geoprocessing is a set of computational resources still little used by Odontology, despite its many using possibilities. It is a valuable tool to be exploited by research in oral health and by SUS, because it helps in planning actions and policies in line with the principles of SUS decentralization and territorialization.

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