

## Chart selection appropriate for articles in the field of medicine, dentistry and health sciences

### Właściwy dobór wykresów w artykułach medycznych, stomatologicznych i nauki o zdrowiu

**Ricardo Grillo, Adalmir Gonzaga dos Santos Queiroz, Claudio Roberto Pacheco Jodas, Rubens Gonçalves Teixeira**

Oral surgery, São Leopoldo Mandic, Brazil  
Protetyka Stomatologiczna, Brazylia  
Head: Prof. Ricardo Grillo

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#### KEY WORDS:

graphics, charts, treemaps, histogram, data representation, manuscript preparation, writing guidelines, retrospective studies

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#### HASŁA INDEKSOWE:

ilustracje, wykresy, wykresy zagnieżdżonych kwadratów, histogram, przedstawianie danych, przygotowanie manuskryptu, pisanie wytycznych, badania retrospektywne

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#### Summary

**Aim of the study.** An image has the power to facilitate comprehensibility of complex data. The aim of this paper is to discuss chart selection in medicine, dentistry and health sciences articles, increasing data comprehension and memorization.

**Methods.** Design, mathematical, statistics, health, and technology papers, books and websites were used to best describe data visualization through graphic use. Authors searched MEDLINE, Cochrane Library, and grey literature for chart styles and which one best suits specific data. Some articles were included as examples.

**Results.** Some principles of data visualization were discussed. Chart types (comparison, combination, distribution and relationship) were clarified, and a practical guide of selection was performed. Colours option and some aesthetic aspects were considered.

**Conclusions.** An appropriate chart selection is extremely useful to researchers and readers, making data more assimilable.

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#### Streszczenie

**Cel pracy.** Obraz ułatwia zrozumienie złożonych danych. Celem niniejszego artykułu jest omówienie doboru odpowiednich wykresów w artykułach o tematyce medycznej, stomatologicznej i naukach o zdrowiu, usprawniających możliwości przyswojenia danych oraz ich zapamiętania.

**Metody.** Wykorzystano książki, strony internetowe oraz artykuły z zakresu dizajnu, matematyki, statystyki, nauk o zdrowiu i technologii w celu jak najlepszego opisanie wizualizacji danych poprzez użycie wykresów. Bibliograficzne bazy danych (MEDLINE, Cochrane Library) oraz publikacje z zakresu szarej literatury zostały użyte w poszukiwaniu stylów wykresów oraz dopasowania ich do konkretnych typów danych. Niektóre artykuły wykorzystano jako przykłady.

**Wyniki.** Omówiono niektóre zasady wizualizacji danych. Typy wykresów (porównania, kombinacje, rozkłady i zależności) zostały wyjaśnione; przedstawiono również praktyczny przewodnik ułatwiający dobór wykresu do konkretnego rodzaju danych. Przedyskutowane zostały opcje kolorystyczne oraz elementy poprawiające estetykę.

**Wnioski.** Właściwy dobór wykresów ma ogromne znaczenie dla badaczy oraz czytelników sprawiając, że dane są łatwiej przyswajalne.

## Introduction

“*A picture is worth a thousand words*” and any graphical representation behaves as a picture, communicating a clearer message.<sup>1</sup> A chart has the possibility to elucidate and summarize plenty of crucial data, and for this reason is largely used in scientific papers. An appropriate graph embodies massive data and can replace some exhaustive and hard to handle tables, illustrate trends, relations or simply publish raw data.<sup>2</sup> The question of chart selection is crucial since a wrong path could lead to an inappropriate data visualization, causing more confusion rather than elucidating.

A figure/photograph can communicate fundamental information to a scientific article reader, especially regarding a new surgical technique, an outstanding biomaterial or a specific anatomical region. One obstacle lies in transposing data or numbers to a figure in a way that facilitates not only understanding but also memorization of these data. Due to the large availability of numbers and written data, charts are largely used in scientific papers, useful for data presentation, comparisons, relationships or even composition. Graph utilization is getting wider since the majority of journals are presented in digital formats, with no restriction to colours.<sup>3</sup> Graphic representation of data is known as data visualization or “*data viz*”.

The aim of this paper is to create a practical guide in chart selection. Crucial questions about what kind of data and how these data can be displayed have been elucidated. Basic principles of data visualization have been debated. Variables, items, categories, and outcomes amount presentation have also been discussed.

## Material and methods

This is an original article about graphical analysis in scientific articles and has followed

no guideline. A bibliographic search concerning design, mathematical, technology and health science articles, books and websites was performed and steps on choosing which chart is ideal for spreading research findings were analysed. The authors searched MEDLINE, Cochrane Library, and grey literature for chart styles to find which one best suits specific data. Some articles were included as examples. Literature regarding health articles and chart selection is scarce.

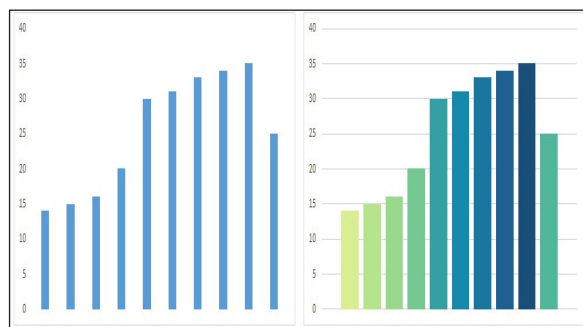
Example tables and charts were created through Microsoft Excel and PowerPoint (Microsoft, Richmond, VA, USA), and XLSTAT (Addinsoft Inc, Paris, France). Forest plot example was created through Review Manager Software 5.4 (Review Manager (RevMan) [Computer program]. Version 5.4. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). Network visualization was performed through VOSviewer (VOSviewer, Leiden University, The Netherlands).

A practical guide to chart selection was performed to help authors to choose which chart best suits medicine, dentistry and health sciences scientific papers. Readers can also benefit from this knowledge, due to a more efficient interpretation of the data and graphs presented.

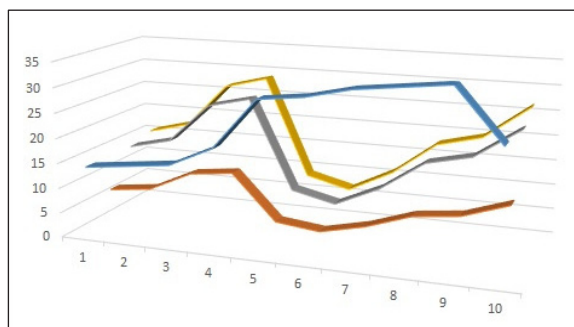
## Results

### *Principles of data visualization*

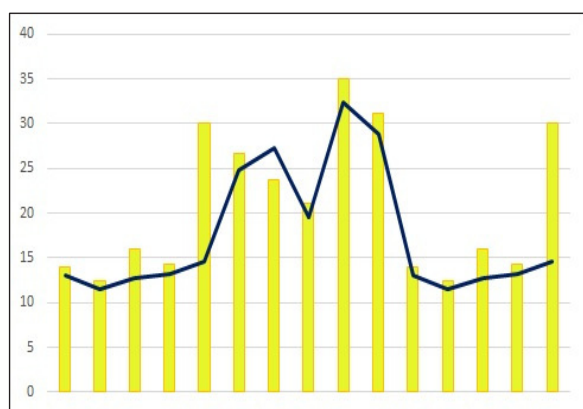
Some attributes are related to a high-quality graph including easy to read dots and lines, visually balanced axes and scales. The chart itself must deliver a message without referring back to the text.<sup>1</sup> Colour optimization brings higher effectiveness, enhancing visibility;<sup>4,5</sup> a colour palette use with balancing and contrasting colours is very useful to achieve this purpose.<sup>6-8</sup> A coherent order of colours allows a meaningful interpolation, achieving



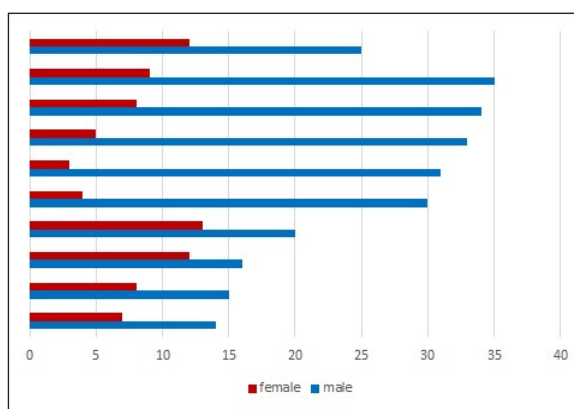
**Fig. 1.** Two bar charts with the same data. A more pleasant visual can be achieved with colour palette and gridlines.



**Fig. 2.** A three-dimensional chart, not so clear.



**Fig. 3.** A combination between a bar chart (yellow) and a line chart (blue).



**Fig. 4.** A grouped in male and female horizontal bar chart.

a more pleasant visual result (figure 1).<sup>9</sup> Free and easy to use colour palettes are available on the internet. Even if we are not dealing with a photograph, and efficient edition must be performed in order to obtain a better graphical image. The majority of journals use a pattern of 300 dots per inch (DPI) as minimum resolution. A variety of charts can be helpful in scientific papers.

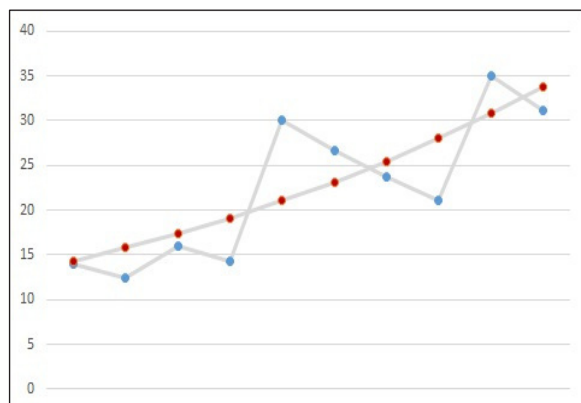
Care must be taken in inclusion of aesthetic appeal elements. When overly used, they reduce the effectiveness of visualization by obscuring the intended message.<sup>10</sup> The excessive use of three-dimensional charts, stereo and motion depth can disturb visualization (figure 2).<sup>11</sup> A helpful tool is a combination chart, two or more chart types in a single chart; a helpful combination, typical in epidemiological

analysis, is a bar chart and a line chart (figure 3).<sup>12</sup>

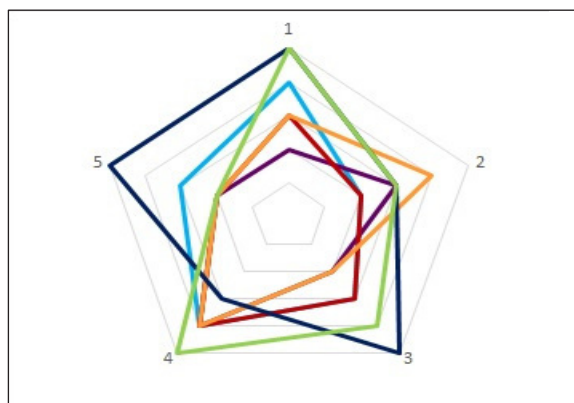
Two questions are fundamental when selecting a chart. To this purpose a display form must be selected. A chart can be used for data visualization of composition, comparison, distribution, and relationship. Another crucial information is how these data behave in relation to time, whether they are static or dynamic.

#### *Comparison charts*

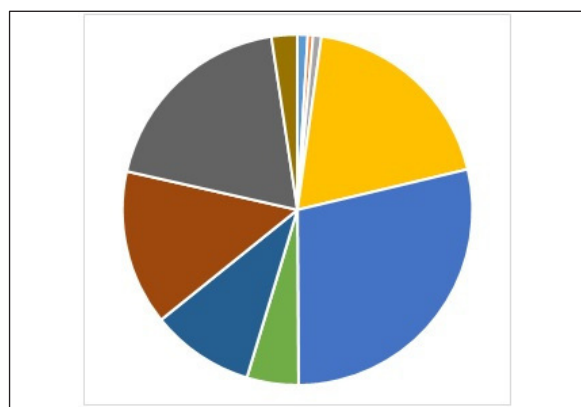
Comparison charts are used to present data, their magnitude and proportionality. This comparison can be measured among items, using a bar chart, or over time. Bar chart or line charts are useful to compare non-cyclical data, bar chart for a single or several categories and line chart used for many categories. Bar



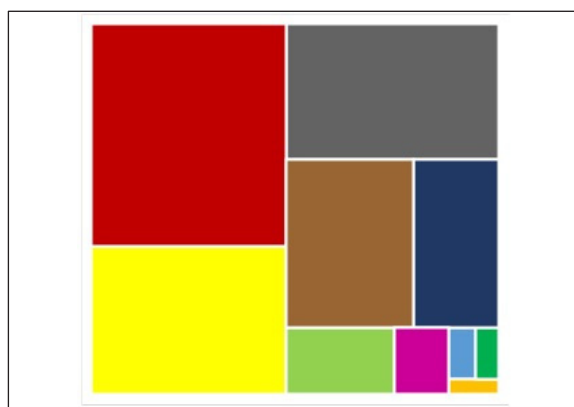
*Fig. 5. A control chart example.*



*Fig. 6. A radar chart example.*



*Fig. 7. A pie chart example. Confusion to the eyes can be caused due to difference between variables size.*



*Fig. 8. A treemap with the same data of pie chart figure 3. Clearer visual comprehension, even with great variable size between groups.*

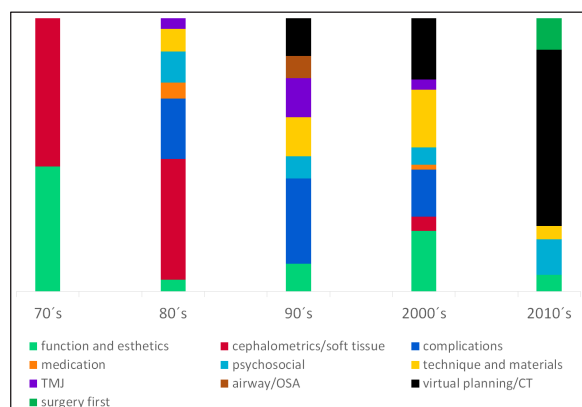
charts can be grouped (figure 4),<sup>13</sup> displaying the same data on absolute and proportional variables, study and experimental groups,<sup>14</sup> different years, genders,<sup>15</sup> etiology,<sup>16</sup> or age range.<sup>17</sup> Horizontal or vertical bar charts can be used for the same purpose<sup>18</sup> but a horizontal bar chart is usually employed when many data are available. A minor modification of line chart is addition of a single dot on time; this chart is a control chart (figure 5).<sup>19</sup> Plotted in time order, it is useful for changing data over time.

A rather uncommon comparison chart, variable width column chart, can be used for comparison among items with two variables per item. Cyclic multivariate data can be charted

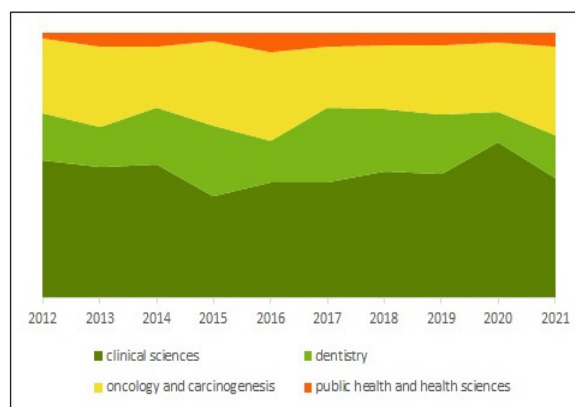
using a radar chart (figure 6), a useful graph for multidimensional visualization,<sup>20</sup> helpful in the control of quality improvement and strengths and weaknesses, i.e. distinct trademarks, biomaterials<sup>21</sup> or gene expression.<sup>22</sup>

#### *Composition charts*

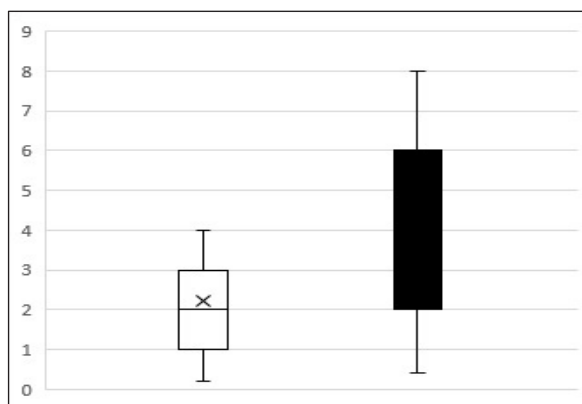
This type of charts shows individual parts and percentage of each part in a whole composition, exhibiting relative or absolute values. A composition chart is helpful in demonstrating static data through a pie chart, a stacked bar chart or a treemap. A pie chart is used to demonstrate a simple share of the whole and even though it is a frequently used chart,<sup>23</sup> it is considered a very poor graphical



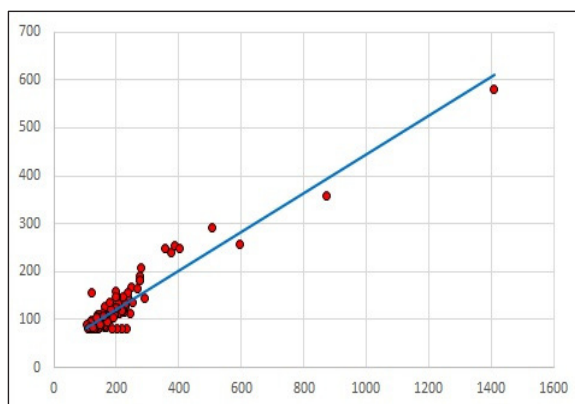
**Fig. 9.** Stacked bar chart about the number of publications in orthognathic surgery topics over decades.



**Fig. 10.** Stacked area chart of ameloblastoma publications and journals research categories.



**Fig. 11.** A boxplot example chart.



**Fig. 12.** Scatterplot assessing Pearson's correlation between the number of citations about orthognathic surgery in two different search platforms.

analysis.<sup>24</sup> A pie chart using many variables can cause some visual confusion (figure 7).

A treemap has multiple advantages<sup>25</sup> over a pie chart including visual processing, labeling, color-coding, sizing and multi-level data; a helpful chart in scientific papers analyzing static composition regardless of the number of variables. A treemap could be especially useful in epidemiological analysis making understanding of the data more assimilable than a pie chart (figure 8).

For time-based data, a stacked bar chart (figure 9) can be used to demonstrate a few periods dynamic data,<sup>26,27</sup> while a stacked area (figure 10) is useful when a larger number of periods are evaluated. A stacked bar or stacked

area charts can be used in dynamic analysis, including epidemiological comparisons over time, i.e. anatomic site involved in a trauma and age range<sup>12</sup> or percentage responses.<sup>28</sup>

#### Distribution charts

Frequency distribution displays the frequency of various outcomes in a sample, containing the frequency or a number of occurrences related to a particular group or interval.<sup>29</sup> A histogram is a regularly used distribution chart, as is a bar histogram or a line histogram. A bar histogram is preferable when outcomes are not on same range, resulting in unequal width bars, a crucial difference to bar charts. Some formulae, not so elementary, are used to figure out the bar width

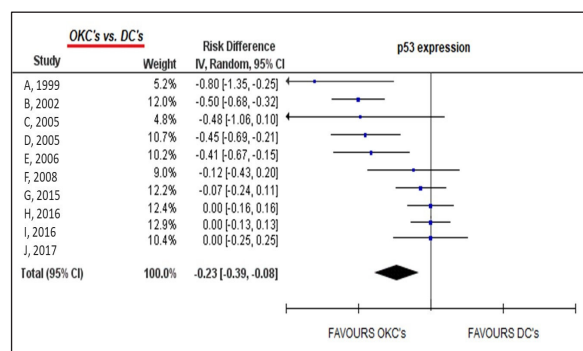


Fig. 13. A forest plot example created with RevMan 5.4

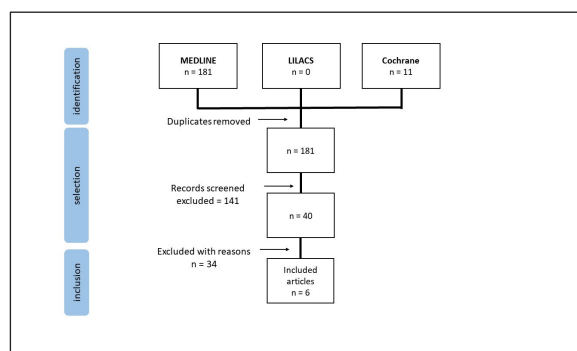


Fig. 14. A flowchart example.

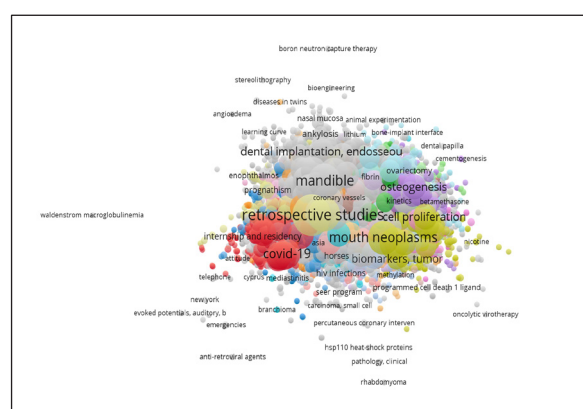


Fig. 15. Keyword network visualization of oral and maxillofacial surgery articles created with VOSviewer.

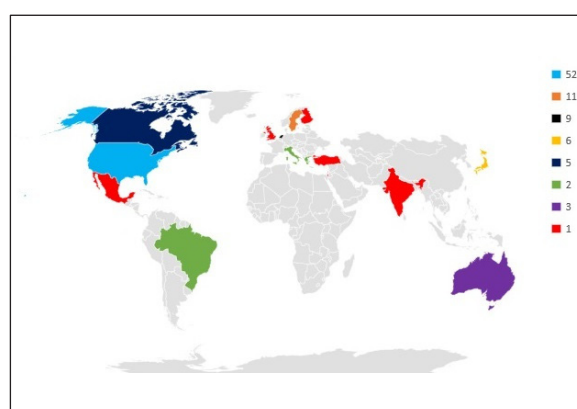


Fig. 16. A country map chart example.

on a histogram, many of them with a Gaussian assumption.<sup>30</sup>

Line histograms are more useful in papers with more numerous outcomes.<sup>31</sup> Line histograms or line charts are helpful tools for distribution statistical tests like t-Student, Chi-square, Kolmogorov-Smirnov and Shapiro-Wilkes tests.

A singular distribution chart is a boxplot, a graphical method to assess quartiles (figure 11). One single plot can reveal extremes, upper and lower hinges, median, and outliers.<sup>32</sup> It is very useful in exploring data and understanding the studied information,<sup>33</sup> i.e. effect of a determined medication to third molar surgery<sup>34</sup> or a biomarker level.<sup>35</sup>

*Relationship charts*

A scatterplot is a singular example of a relationship chart, versatile, polymorphic,<sup>36</sup> it can also be used as a distribution chart, when multivariable data are involved.<sup>37</sup> Relationship charts are used to find correlations, outliers, clusters and trendship assessment between two variables. Three or more variables can be analysed through a bubble scatterplot. Scatterplots are employed on trendlines and correlation between variables using Pearson’s (figure 12) or Spearman’s correlations is helpful.

Some other charts are only variations of the charts presented above and are not usually used in scientific articles (funnel charts, bullet graphs or heat maps). On the other hand, there are two charts created specifically for scientific articles. A forest plot, or a blobogram (figure 13) is a

type of graphical display performed to represent a meta-analysis,<sup>38,39</sup> summarizing results of randomized controlled trials.<sup>40</sup> A flowchart (figure 14) is a graphical representation of identification, election and inclusion of articles in a systematic review,<sup>41</sup> a mandatory step according to PRISMA guideline.<sup>42</sup> Although not mandatory, flowcharts are highly recommended to be used in CONSORT (randomized clinical trials)<sup>43</sup> and STROBE (cohort studies)<sup>44</sup> statements.

A network visualization graph (figure 15) is a mathematical structure useful for representation of relations and changes between points.<sup>45</sup> Very useful in bibliometrics to evaluate citations and authors occurrences,<sup>46</sup> it can be created with some free softwares like VOSviewer<sup>47</sup> and CiteSpace.<sup>48</sup> A map chart can be made to assess country, region, or cities differences (figure 16).

## Conclusions

Selection of an appropriate chart is fundamental for data visualization, making information clearer, useful to researchers. It is a crucial step towards a more comprehensive information absorption and memorization, helpful for the readers, editors and reviewers.

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 Adres autorów: Department of Oral Surgery, Institute and Research Centre, São Leopoldo Mancic, 13045-755 Campinas, SP, Brazil  
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