Statistical methods used in articles published by the *Journal of Periodontal and Implant Science*

Eunsil Choi[1], Jiyoung Lyu[1], Jinyoung Park[1], Hae-Young Kim[1,2,*]

[1]BK21 PLUS Program in Embodiment: Health-Society Interaction, Department of Public Health Sciences, Graduate School, Korea University, Seoul, Korea

[2]Department of Health Policy and Management, College of Health Sciences, Korea University, Seoul, Korea

Purpose: The purposes of this study were to assess the trend of use of statistical methods including parametric and nonparametric methods and to evaluate the use of complex statistical methodology in recent periodontal studies.

Methods: This study analyzed 123 articles published in the *Journal of Periodontal & Implant Science* (JPIS) between 2010 and 2014. Frequencies and percentages were calculated according to the number of statistical methods used, the type of statistical method applied, and the type of statistical software used.

Results: Most of the published articles considered (64.4%) used statistical methods. Since 2011, the percentage of JPIS articles using statistics has increased. On the basis of multiple counting, we found that the percentage of studies in JPIS using parametric methods was 61.1%. Further, complex statistical methods were applied in only 6 of the published studies (5.0%), and nonparametric statistical methods were applied in 77 of the published studies (38.9% of a total of 198 studies considered).

Conclusions: We found an increasing trend towards the application of statistical methods and nonparametric methods in recent periodontal studies and thus, concluded that increased use of complex statistical methodology might be preferred by the researchers in the fields of study covered by JPIS.

Keywords: Nonparametric statistics, Periodontal diseases, Statistical data interpretation, Statistics.

INTRODUCTION

Statistical methodology plays a critical role in the design of scientific studies, analysis of scientific data, interpretation of results, and drawing of conclusive statements. Therefore, appropriate statistical reasoning is gaining increasing importance in the field of scientific research. As misused statistics and inadequate interpretation may lead to an erroneous conclusion of a scientific study, many previous studies have investigated the occurrence of statistical errors in various fields of scientific health research [1-4]. Frequent statistical errors were found in procedures for calculating the sampling size, checking the assumptions of statistical methods, and confirming the independence in a traditional analysis. In an effort to solve such problems, the International Committee of Medical Journal Editors formulated important basic guidelines related to statistical analysis, stating that authors should provide

a sufficient amount of detail of a statistical analysis to enable a reader to verify the reported results and that they need to apply appropriate indicators of measurement errors or uncertainty. Further, they recommended specifying the computer programs used [5]. Moreover, the consolidated standards of reporting trials (CONSORT), which have been developed to improve the quality of reporting randomized clinical trials, require the authors to clarify the methods of sample size calculation, the statistical methods used to compare groups for primary and secondary outcomes, and the methods used for additional analyses such as subgroup analysis and adjusted analysis [6].

With respect to the trend of statistical analysis methods, Altman [7] summarized 13 studies that had reviewed the quality of statistics in medical journals from 1966 to 1996 and found that the percentage of acceptable papers from a statistical viewpoint increased from only 10% to 61% in thirty years. Moreover, medical researchers' general understanding of basic statistical methods, such as the *t*-test or the chi-square test, had improved during the thirty-year period [7]. A considerable increase in the use of statistics and a much greater use of complex statistical methodology have been detected in medical research [7], while an increase in the use of complex methods including multivariate or specific methods was not detected in dental research between 1996 and 2006 [8]. In the field of dentistry, generally, aggregate data at the subject level are used for a statistical analysis, while the data collection unit is each tooth or surface (mesial, distal, etc.), which is an important reason that complex statistical methodologies have not been used frequently in the field of dentistry. Some dental data are not easily applicable by using a simple traditional statistical methodology. This could be attributed to one or more of the following factors: multiple observations from a person; reliability problem of measures; frequent ordinal data such as gingival bleeding index or oral hygiene index; count data whose distribution is non-normal such as number of caries teeth; and repeated measurements to measure improvement by intervention or treatment. These are specific conditions where complex analysis methods such as mixed effect modeling or nonparametric statistical methods need to be applied instead of traditional simple parametric methods.

The main purposes of this study were to assess the trend of the application of statistical methods including parametric and non-parametric methods and to evaluate the use of complex statistical methodology in recent periodontal studies. We analyzed studies published in the *Journal of Periodontal & Implant Science* (JPIS) to evaluate the recent trend of using statistical methods in scientific research.

MATERIALS AND METHODS

Selection of articles

In this study, we collected 191 articles published in the JPIS between 2010 and 2014. Among them, studies including any statistical method were selected; this led to the selection of a total of 123 articles (64.4%) published in JPIS.

Methods

Categorization of studies that used statistical methods

Among 191 articles published in JPIS, studies were categorized according to whether any type of statistical method was used or not. Further, the number of statistical methods applied was counted.

Categorization of type of statistical techniques applied

The statistical techniques applied were categorized into parametric methods and nonparametric methods. Parametric methods were subdivided into 'simple methods,' including one-way or multiway analysis of variance (ANOVA), independent and paired *t*-test, Pearson correlation, chi-square test, and 'complex methods,' including regression, logistic regression, repeated measures ANOVA, mixed model, Cox regression, generalized linear model (GLM), Poisson regression, analysis of covariance (ANCOVA), and Mantel-Haenszel chi-square method. Nonparametric methods consisted of Mann-Whitney *U*-test, Wilcoxon signed-rank test, Kruskal-Wallis test, Fisher exact test, and Spearman correlation. When multiple statistical techniques were used in a study, each method was counted separately.

Categorization of statistical software packages

The frequency of the use of the statistical software packages provided was counted according to the type of statistical software package used.

Table 1. The number of articles published and the number of articles using statistics in the *Journal of Periodontal and Implant Science.*

	Year					Total
	2010	2011	2012	2013	2014	
No. of published articles	39	40	36	45	31	191
No. of articles using statistics	19	28	28	30	18	123
% Using statistics	48.7	70.0	77.8	66.7	58.1	64.4

Table 2. The number of statistical techniques applied in the articles using statistics in the *Journal of Periodontal and Implant Science.*

No. of methods	Year					Total
	2010	2011	2012	2013	2014	
1	15 (83.3)	18 (66.7)	15 (60.0)	12 (41.4)	3 (18.8)	63 (54.8)
2	3 (16.7)	6 (22.2)	9 (36.0)	12 (41.4)	2 (12.5)	32 (27.8)
3	0 (0)	2 (7.4)	0 (0)	3 (10.3)	7 (43.8)	12 (10.4)
4	0 (0)	0 (0)	1 (4.0)	2 (6.9)	2 (12.5)	5 (4.3)
≥5	0 (0)	1 (3.7)	0 (0)	0 (0)	2 (12.5)	3 (2.6)
Total	18 (100)	27 (100)	25 (100)	29 (100)	16 (100)	115 (100)
Mean	1.17	1.52	1.48	1.83	3.00	1.72±0.99[a]

Values are presented as number (%) unless otherwise indicated.
[a]Mean±standard deviation.

RESULTS

Frequency of statistical methods

One hundred twenty-three articles (64.4%) published in JPIS between 2010 and 2014 used one or more statistical methods (Table 1). Since 2011, the percentage of articles using statistics in JPIS has increased to more than 55% as compared to 48.7% in 2010. On average, the number of statistical techniques used in JPIS was about 1.72. The number of statistical techniques used in JPIS articles increased consistently from 2011 to 2014 (Table 2).

Types of statistical methods: parametric methods

Based on the multiple counting of statistical methods, there were 121 cases (61.1% of the total of 198 cases considered) applying parametric statistical methods in JPIS articles during the period investigated. One-way or factorial ANOVA and independent t-test were the most frequently used parametric tests; 62.8% of JPIS articles used either of these two methods (Table 3). The paired t-test, Pearson correlation, and chi-square test comprised around 10% of all parametric methods used in JPIS. The frequency of parametric methods such as regression and logistic regression was about 4% and 1%, respectively, in JPIS. Among the articles published in JPIS,

Table 3. Frequencies[a] of the parametric statistical techniques applied in the articles published by the *Journal of Periodontal and Implant Science*.

Parametric methods	Year					Total
	2010	2011	2012	2013	2014	
Parametric						
Simple	13 (92.9)	26 (92.9)	21 (95.5)	33 (100)	22 (91.7)	115 (95.0)
ANOVA	7 (50.0)	9 (32.1)	10 (45.5)	14 (42.4)	3 (12.5)	43 (35.5)
Independent t-test	4 (28.6)	8 (28.6)	7 (31.8)	7 (21.2)	7 (29.2)	33 (27.3)
Paired t-test	1 (7.1)	5 (17.9)	2 (9.1)	2 (6.1)	3 (12.5)	13 (10.7)
Pearson Correlation	1 (7.1)	1 (3.6)	1 (4.5)	8 (24.2)	3 (12.5)	14 (11.6)
Chi-square test	0 (0)	3 (10.7)	1 (4.5)	2 (6.1)	6 (25.0)	12 (9.9)
Complex	1 (7.1)	2 (7.1)	1 (4.5)	0 (0)	2 (8.3)	6 (5.0)
Regression	1 (7.1)	2 (7.1)	1 (4.5)	0 (0)	1 (4.2)	5 (4.1)
Logistic regression	0 (0)	0 (0)	0 (0)	0 (0)	1 (4.2)	1 (0.8)
Subtotal	14 (66.7)	28 (68.3)	22 (59.5)	33 (62.3)	24 (52.2)	121 (61.1)
Nonparametric	7 (33.3)	13 (31.7)	15 (40.5)	20 (37.7)	22 (47.8)	77 (38.9)
Total	21 (100)	41 (100)	37 (100)	53 (100)	46 (100)	198 (100)

Values are presented as number (%).
ANOVA: analysis of variance.
[a]Multiple counting was applied for articles with multiple statistical methods.

Table 4. Frequencies[a] of the nonparametric statistical techniques applied in the articles published by the *Journal of Periodontal and Implant Science*.

Nonparametric methods	Year					Total
	2010	2011	2012	2013	2014	
Mann-Whitney U/Wilcoxon rank-sum test	1 (14.3)	4 (30.8)	5 (33.3)	6 (30.0)	4 (18.2)	20 (26.0)
Wilcoxon signed rank test	3 (42.9)	4 (30.8)	7 (46.7)	3 (15.0)	5 (22.7)	22 (28.6)
Kruskal-Wallis test	1 (14.3)	2 (15.4)	3 (20.0)	6 (30.0)	3 (13.6)	15 (19.5)
Spearman correlation	1 (14.3)	1 (7.7)	0 (0)	4 (20.0)	2 (9.1)	8 (10.4)
Fisher exact test	1 (14.3)	1 (7.7)	0 (0)	1 (5.0)	3 (13.6)	6 (7.8)
Friedman test	0 (0)	0 (0)	0 (0)	0 (0)	2 (9.1)	2 (2.6)
Kolmogorov-Smirnov/Shapiro-Wilk test	0 (0)	1 (7.7)	0 (0)	0 (0)	3 (13.6)	4 (5.2)
Subtotal	7 (33.3)	13 (31.7)	15 (40.5)	20 (37.7)	22 (47.8)	77 (38.9)
Parametric	14 (66.7)	28 (68.3)	22 (59.5)	33 (62.3)	24 (52.2)	121 (61.1)
Total	21 (100)	41 (100)	37 (100)	53 (100)	46 (100)	198 (100)

Values are presented as number (%).
[a]Multiple counting was applied for articles with multiple statistical methods.

none of the following methods were found: repeated measures ANOVA, mixed model, GLM, Poisson regression, Mantel Haenszel chi-square test, and ANCOVA. In JPIS, complex statistical methods were used in only 6 of the published studies (5.0%).

Types of statistical methods: nonparametric methods

Based on multiple counting, 77 cases (38.9% of the 198 cases considered) of nonparametric statistical methods were found during the investigated period (Table 4). The most frequent nonparametric methods used were Mann-Whitney U-test, Wilcoxon signed-rank test, and Kruskal-Wallis test. The summed percentage of the use of these three methods among the JPIS articles considered was 74.1% of all nonparametric methods. Spearman correlation analysis comprised 10.4% of all nonparametric methods reported in the considered articles. The percentages of Fisher exact test and Kolmogorov-Smirnov test were 7.8% and 5.2% in the articles considered. The McNemar test was not used in any of the studies considered.

Types of statistical software packages

Among the published studies that used statistical analysis, 76.4% provided the details of the statistical software packages used for analysis (Table 5). More than 20% did not provide any details of the statistical software used. However, in JPIS, a remarkable reduction

Table 5. Frequency with which the statistical software packages used in articles published in the *Journal of Periodontal and Implant Science*.

Statistical software	Year					Total
	2010	2011	2012	2013	2014	
Specified	14 (73.7)	17 (60.7)	20 (71.4)	25 (83.3)	18 (100)	94 (76.4)
Nonspecified	5 (26.3)	11 (39.3)	8 (28.6)	5 (16.7)	0 (0)	29 (23.6)
Total (using statistics)	19 (100)	28 (100)	28 (100)	30 (100)	18 (100)	123 (100)

Values are presented as number (%).

Table 6. Type of statistical software packages used in articles in articles published in the *Journal of Periodontal and Implant Science*.

Type	Year					Total
	2010	2011	2012	2013	2014	
SPSS	14 (100)	16 (94.1)	16 (76.2)	19 (67.9)	17 (70.8)	82 (78.8)
SAS	0 (0)	1 (5.9)	2 (9.5)	2 (7.1)	3 (12.5)	8 (7.7)
STATA	0 (0)	0 (0)	1 (4.8)	1 (3.6)	1 (4.2)	3 (2.9)
Microsoft Excel	0 (0)	0 (0)	0 (0)	2 (7.1)	1 (4.2)	3 (2.9)
R	0 (0)	0 (0)	0 (0)	1 (3.6)	1 (4.2)	2 (1.9)
MedCalc	0 (0)	0 (0)	0 (0)	2 (7.1)	1 (4.2)	3 (2.9)
Other[a]	0 (0)	0 (0)	2 (9.5)	1 (3.6)	0 (0)	3 (2.9)
Total	14 (100)	17 (100)	21 (100)	28 (100)	24 (100)	104 (100)

Values are presented as number (%).
[a]Other: GraphPad Prism, Instat, and MATLAB.

in the percentage of articles not reporting the software used was detected between 2010 (26.3%) and 2014 (0.0%). The SPSS (SPSS Inc., Chicago, IL, USA) was predominantly used in the studies considered (78.8%). In JPIS articles, SAS (SAS Institute Inc., Cary, NC, USA) and STATA (StataCorp LP., College Station, TX, USA) were used in less than 10% (7.7% and 2.9%) of the studies. Recently, MedCalc (MedCalc, Ostend, Belgium) has been used in a few studies published in JPIS (Table 6).

DISCUSSION

The results of this study showed a trend of increasing application of statistical methods and increasing use of nonparametric methods in recent periodontal studies in Korea. The percentage of studies using statistics published in JPIS between 2010 and 2014 was 64.4%, which is higher than the 19.3%, 49.0%, and 63.1% in periodontal studies published in Korea during the periods of 1973-1989, 1990-1999, and 2000-2006, respectively [9,10]. Therefore, there was a trend towards increasing use of statistical applications. In prosthodontics research in Korea, around 70% of the studies have reported the use of statistics [11,12]; similarly, around 70% of medical research studies have reported the use of statistics [4]. With respect to the type of statistical methods used in the studies we considered, the percentage of studies using parametric and nonparametric methods was 61.1% and 38.9%, respectively. The percentage of parametric methods was slightly lower than the percentage of parametric methods (>75%) used in periodontal studies published in 1973-1999 and 2000-2006, in orthodontic and prosthodontic research published in 1999-2003 [11-13]. 'Simple' parametric methods such as ANOVA, t-test, Pearson correlation, and chi-square test comprised 95% of all parametric methods used in studies published in JPIS. Complex methods including regression, mixed model, and Cox regression were used in about 5% or less of the studies published in JPIS or in other Korean dental research areas [11-13].

Sterne et al. [14] argued that there were five particular problems in analyzing data from periodontal research: multiple measurements made in each subject, the large magnitude of measurement error as compared to the changes in the attachment level, the analysis of longitudinal studies, the lack of measures of the instantaneous rate of attachment loss, and controversies over the nature of progression of the disease. Some data arising from periodontal research were difficult to analyze with standard statistical methods. Common response variables in periodontal research are the loss of connective tissue attachment measured using a periodontal probe, the measures of gingival inflammation, or alveolar bone levels measured by radiography of each tooth. However, common explanatory variables such as gender, age, or smoking habits are measured at the subject level. Therefore, modeling site-level responses to explanatory subject characteristics causes problems of nonindependence of sites within the same subject [14]. Therefore, applying complex analytic techniques that could reflect these data structures is needed. To reduce errors in the measurement of periodontal attachment and improve

the precision of estimates, the attachment levels were measured using special instruments such as pressure probes, automated probes, and electronic probes.

Evaluation of the distribution of a dependent variable is critical in choosing the appropriate analytic method. In general, traditional parametric analysis requires data to meet basic assumptions such as normal distribution or equal variances. Therefore, the distribution of a continuous dependent variable needs to be assessed before applying such parametric methods. If the assumptions are not met, the researcher should consider the transformation of the dependent variable or choose an appropriate alternative analytic method such as a nonparametric method. In the field of dentistry, ordinal variables such as plaque index, gingival index, and periodontal disease index are used frequently. Sometimes, inattentive researchers neglect to check the nature of variables and erroneously apply parametric methods based on the assumption of normal distribution to ordinal outcome variables. As an inappropriate application of analytic methods may lead to false conclusions, researchers should be careful in selecting the appropriate analytic method.

In conclusion, we found an increasing trend towards the application of statistical methods and nonparametric methods in recent periodontal studies and thus, have concluded that increased use of complex statistical methodology may be preferred by researchers.

CONFLICT OF INTEREST

No conflict of interest relevant to this article has been reported.

ORCID

Eunsil Choi *http://orcid.org/0000-0003-0320-9638*
Jiyoung Lyu *http://orcid.org/0000-0002-7228-4212*
Jinyoung Park *http://orcid.org/0000-0002-8762-6908*
Hae-Young Kim *http://orcid.org/0000-0003-2043-2575*

REFERENCES

1. Gore SM, Jones IG, Rytter EC. Misuse of statistical methods: critical assessment of articles in BMJ from January to March 1976. Br Med J 1977;1:85-7.
2. Schor S, Karten I. Statistical evaluation of medical journal manuscripts. JAMA 1966;195:1123-8.
3. Kim JS, Kim DK, Hong SJ. Assessment of errors and misused statistics in dental research. Int Dent J 2011;61:163-7.
4. MacArthur RD, Jackson GG. An evaluation of the use of statistical methodology in the Journal of Infectious Diseases. J Infect Dis 1984;149:349-54.
5. Uniform requirements for manuscripts submitted to biomedical journals. International Committee of Medical Journal Editors. N Engl J Med 1997;336:309-15.
6. Moher D, Hopewell S, Schulz KF, Montori V, Gotzsche PC, Devereaux PJ, et al. CONSORT 2010 Explanation and Elaboration: updated guidelines for reporting parallel group randomised trials. J Clin Epidemiol 2010;63:e1-37.
7. Altman DG. Statistical reviewing for medical journals. Stat Med 1998;17:2661-74.
8. Vahanikkila H, Nieminen P, Miettunen J, Larmas M. Use of statistical methods in dental research: comparison of four dental journals during a 10-year period. Acta Odontol Scand 2009;67:206-11.
9. Nam MS, Jeon CK, Shin KY, Han KY, Kim BO. Evaluation of statistical analysis of articles in Journal of Korean Academy of Periodontology. J Korean Acad Periodontol 2000;30:699-706.
10. Kim YJ, Jang HS, Kim BO. Evaluation of statistical methods in the Journal of Korean Academy of Periodontology published from 2000 to 2006. J Korean Acad Periodontol 2009;39:399-405.
11. Park DG, Choi YG, Kim YS, Shin SW. An assessment of statistical errors of articles in the Journal of Korean Academy of Prosthodontics: comparison between Korean version and English version. J Korean Acad Prosthodont 2009;47:273-85.
12. Kang DW, Seo Y, Oh NS, Lim HJ. Assessment of statistical errors of articles published in the Journal of the Korean Academy of Prosthodontics: 2006-2010. J Korean Acad Prosthodont 2012;50:258-70.
13. Lim HJ. A review of statistical methods in the Korean Journal of Orthodontics and the American Journal of Orthodontics and Dentofacial Orthopedics. Korean J Orthod 2004;34:371-9.
14. Sterne JA, Curtis MA, Gillett IR, Griffiths GS, Maiden MF, Wilton JM, et al. Statistical models for data from periodontal research. J Clin Periodontol 1990;17:129-37.