REVIEW ARTICLE

COMMON STATISTICAL TESTS IN DENTAL RESEARCH

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ABSTRACT:
Background: The knowledge of statistical analysis is essential before planning any research study .Clinical studies often compare the efficacy of a new treatment in a study group with the efficacy of conventional treatment, or with a control group. Aside from a pure description, we would like to know whether the observed differences between the treatment groups are just random or are really present. This article informs the reader about frequently used statistical tests and their application in dentistry. Methods: The most commonly used statistical tests are identified through a selective literature search on the methodology of dental research publications. This article provides a brief overview of the type of statistical tests to analyze research data with its examples. Results and conclusions: This article describes the criteria for choosing the proper statistical test. Simple flowchart and tables are provided to facilitate the selection of the appropriate test. The present article discusses frequently used statistical tests for different scales of measurement and types of samples which enables the clinician to apply the correct statistical test in scientific publications and thus correctly interpret findings.
Key words: Statistical test, data, variable, correlation, association.

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This article may be cited as: Jain S, Gupta A, Jain D. Common Statistical Tests in Dental Research. J Adv Med Dent Scie Res 2015;3(3):38-45.

INTRODUCTION: Statistics is considered as a branch of mathematics for collection and interpretation of data.[1] Biostatistics is that branch of statistics related to biological events. Statistics has two main basic types: descriptive statistics (set of methods to describe the collected data) and inferential statistics (set of methods to generalize, predict and decide by using information from a sample and inferring something about population). Both branches of statistics collectively are sometimes referred to as applied statistics.[2] The basic knowledge of statistical analysis is very important tool before planning any research study. It is quite common to find dental students, clinicians and new researchers having certain lack of understanding on how suitable statistics tests can be obtained. Several steps are important in the statistical analysis, out of which the most important one is the choice of the appropriate statistical test. Selecting suitable statistical test would enables the clinician to make correct diagnosis. A misunderstanding could lead the researcher to wrong conclusions. Before choosing any statistical test first ask ourself what is our research question? Whether we are interested in – Association - t test, ANOVA, chi square, Correlations- Pearson's and Spearman's correlation coefficient, Prediction- linear regression, logistic regression. Before choosing the proper statistic analysis one must have clear understanding about following:

Variable: A variable is any condition that can vary or change in quantity or quality. Variable can be independent variable or dependent, discrete or continuous, alternative (binary) or non alternative variable.

- The independent variable, or treatment, is under the control of and administered by the experimenter. The behavior that is potentially affected by the treatment and that we measure is called the dependent variable. It is referred to as dependent because a change in it depends on the effect of the independent variable.

Examples of dependent variables are

- Type and nature of tooth movement
- Speed of tooth movement
- Retention of tooth position

- Amount of root resorption
- Patient compliance
- Pain experience of patient
- Patient satisfaction
- Ridge resorption
- Retention , support, stability of denture

Examples of independent variables are

- Age
- Sex
- Race
- Concern for their own dental occlusion and appearance
- Orthodontic force
- Wish for treatment
- Positive attitude towards braces

- Discrete variable has limited or countable number of values and the basic unit of measurement cannot be meaningfully subdivided eg. number of dental students in a class , number of daily admissions of patients in hospital etc whereas continuous variable has an infinite number of possible values and its basic unit of measurement can be meaningfully subdivided.eg height , weight, skull circumference, meter is a unit of length; it can be subdivided into centimeters, millimeters etc.

- Alternative (Dichotomous or binary) data represent measurable categories in that outcome can take only one of two values: yes or no, "improved/not improved" and "completed task/failed to complete task." Non-Alternative represent measurable categories in that outcome can take many values. Example is severity of disease level (mild, moderate, severe)

Data and their types (flowchart 1)

Data can be broadly classified into- Qualitative data or Quantitative data[3]

Qualitative Data:

- Measuring a characteristic for which there is no natural numeric scale (can be subdivided into nominal and ordinal data) .Example:- Gender, Eye color, a child may or may not show evidence of dental caries at a particular moment in time. In this case the observation describes the presence or absence of a characteristic, and it is therefore qualitative rather than quantitative.

Quantitative Data:

- There is a natural numeric scale (can be subdivided into interval and ratio data) Example:- height, weight age etc.

Scales of Measurement:

The scale of measurement has implications for the way information is displayed and summarized and determines the statistical methods for analyzing the data. There are 3 scales of measurements in statistics: (Table 1)

Nominal (classificatory)

Ordinal (ranking)

Numerical (Interval and Ratio scales)

Frequently used Statistical test:

Broadly statistical tests are divided into two groups: Parametric and Non parametric (Tests are shown in table 2 and 3)

Selection of appropriate statistical tests

Selection of appropriate statistical test is very important for analysis of research data. Use of wrong or inappropriate statistical test is a common phenomenon observed in articles published in many medical journals (study by Jaykaran 2011) Wrong statistical tests can be seen in many conditions like use of paired test for unpaired data or use of parametric statistical tests for the data which does not follow the normal distribution or incompatibility of statistical tests with the type of data, etc.

Because of the availability of different types of statistical software, performing the statistical tests become easy, but selection of appropriate statistical test is still a problem

Selection of appropriate statistical test depends on the following three things:

A) Whether our data follows normal distribution or not? There are two types of data distribution: Normal and abnormal (also called free-distribution). Normal or Gaussian distribution takes approximately the form of a bell-shaped curve when data is exposed in a curve of distribution. It can be seen that the data cluster around a central point and spread symmetrically around this center point. Many commonly used statistical tests, e.g. Anova, Student t-test, are based on parametric assumptions requiring a normal distribution.[4]When the curve distribution

is not a bell-shaped curve, it is called asymmetrical, abnormal or a free-distribution. Tests for abnormally distributed data are called nonparametric. Examples of parametric and non parametric tests (table 4)

Before analyzing the differences between the groups, it is necessary to check the distribution of the data.[2] Normality tests are used to check the distribution of data.With large enough sample sizes (> 30 or 40), we can use parametric procedures even when the data are not normally distributed. The main tests for the assessment of normality are Kolmogorov-Smirnov (K-S) Test and Shapiro-Wilk test. These tests compare the scores in the sample to a normally distributed set of scores with the same mean and standard deviation; the null hypothesis is that "sample distribution is normal." If the test is significant, the distribution is non-normal. For large sample sizes, significant results would be derived even in the case of a small deviation from normality. It has been reported that the K-S test has low power so Shapiro- Wilk test is usually recommended for testing normality Other than statistical tests normality can also be checked by visual method (box plot) and statistical software (SPSS).

B)What kind of data we are dealing with? Flowchart 2: (Qualitative Vs qualitative, Qualitative Vs quantitative and Quantitative Vs quantitative)

For Qualitative Vs Qualitative:

For Unpaired sample - Fisher's exact test (for small sample)

Chi square test (for large sample)

For Paired sample - McNemar test

For Quantitative Vs quantitative (correlation test eg. Pearson's correlation coefficient)

Homogeneity of variances are a basic assumption of a number of statistical tests, including t test and ANOVA. This can be determined by the following approaches:

- Comparison of graphs especially box plots
- Comparison of variance, standard deviation
- Statistical tests (F test is used to determine whether the variances of two populations are equal. For three or more variables Levene's test and Bartlett's test is used.)

C) What is the aim of the study? The type of study design (paired or unpaired). Samples can be easily classified as paired (or matched) and unpaired (or unmatched).[4]A common paired design occurs when a single group of subjects is measured before and after a procedure to examine the effect of some treatment or measuring a variable on right and left side of same patient or measuring any variable in twins. Independent samples are consisted of different subjects on each group.

Post hoc tests

ANOVA test tells that whether you have an overall difference between your groups, but it does not tell you which specific groups differed .To know which group is different from other, post hoc tests are used. Because post hoc tests are used to confirm whether the differences are there in groups, they should only be used when we have a shown an overall significant difference in group means i.e., a significant one-way ANOVA result. Post-hoc tests are termed a post priori tests as they are performed after the event. Types of various post hoc test (table 6)

When comparing three or more groups, we should not perform a series of t- tests. Instead, use one-way ANOVA followed by post hoc test (which take into account all the comparisons) The problem with pair wise t test is that the significance levels can be misleading. For example, if you have 7 groups, there will be 21 pairwise comparisons of means; if using the .05 level of significance, you would expect at least one statistically significant difference even if no differences exists.

Selection of Post hoc test

The choice of post-hoc test should be determined by equality of the variances, equality of group sizes and by the acceptability of the test in a particular research discipline. For example, Scheffe is often used in psychological medicine, Bonferroni in clinical applications. Different post hoc test can be used for different combinations.

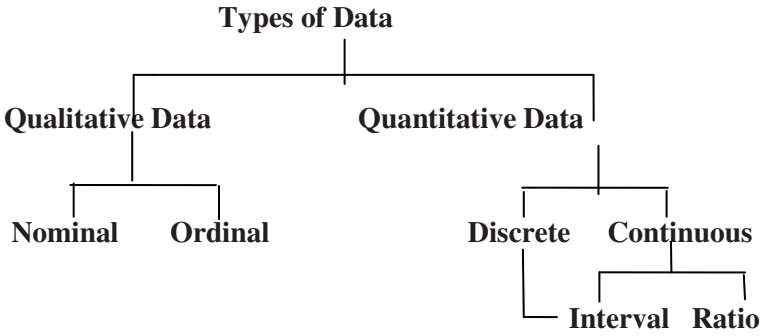
For comparison of every possible combination of groups (X and Y, Y and Z, and Z and X, also compare X and Y+Z, Y and Z+X, Z and X+Y) Scheffe's test is applied.

For comparison of every group (X and Y+Z, Y and Z+X, Z and X+Y)Tukey's test is used.

To compare every group against the control (If control is X, X and Y, and X and Z) Dunnett's test is used.

To compare the data against the within subject factor Bonferroni correction is used. Dunn post test is applied after Kruskal Wallis and Friedmann test.

Flowchart 1: Types of data



Flowchart 2: Statistical tests on the basis of types of data

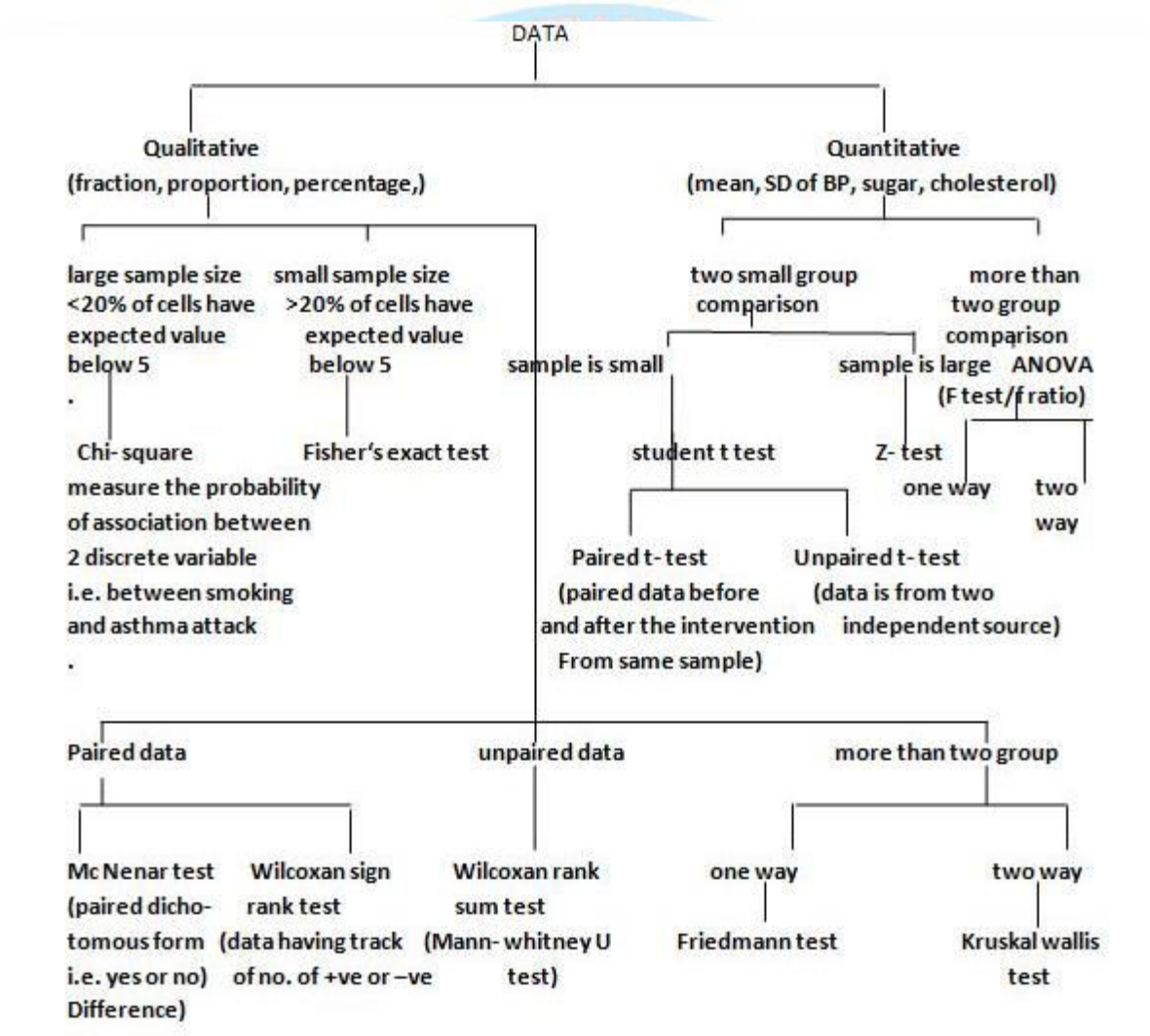


Table 1: Different Scales of measurement

Scales of measurement	Question	Operation that make sense				Examples
		Counting	Ranking	Addition/ Multiplication	Substraction	
Nominal	Is X different than Y?	yes	-	-	-	Gender Race Types of maloccusion
Ordinal	Is X bigger than Y?	yes	yes	-	-	Stages of disease Grades of orthodontic index like IOTN, DAI etc
Interval	By how many unit X and Y differ?	yes	yes	Yes	-	Temperature
Ratio	How many times bigger than Y is X?	yes	yes	Yes	yes	Mandibular length Body length Facial index Cephalic index

Table 2: PARAMETRIC TESTS (Follow normal distribution and Normal curve)

S.No	Statistical test	Description	Example
1	Student t test	Investigates whether the expected values of two groups are the same. The test can be used for paired or unpaired groups. **Unpaired t test**-Difference between means of two unpaired samples. **Paired t test**-Is applied to paired data of observations from one sample only when each individual gives a paired of observations	• To compare electromyographic data of two groups of patients (open and deep skeletal bite) before and after surgical orthodontic treatment
2	Z test	Similar to 't' test in all aspect except that the sample size should be > 30	-
3	ANOVA	Useful for comparison of means of several groups. Is an extension of student's 't' test for more than two groups	
	One way ANOVA	Under one way ANOVA, we consider only one factor and observe the mean of single variable	Comparison of pharyngeal airway volume among different vertical skeletal patterns-high, medium and low angle cases
	Two way ANOVA	Two way ANOVA is used to study the impact of two factors in different groups(3 or more).	-To evaluate the length and orientation of masseter in 3 different types of malocclusions quantitatively using Cone Beam Computed Tomography (CBCT).

Table 3: NON PARAMETRIC TESTS (distribution does not require any specific pattern of distribution. They are applicable to almost all kinds of distribution)

S.No	Statistical test	Description	Example
1.	Chi square test	• To test association between two events in binomial or multinomial samples • As a test of goodness of fit The test is most commonly used on data that are presented in a 2 X 2 table of frequencies.	To evaluate the subjects perceived satisfaction of their dental appearance in different groups. Patient response to vaccum formed splint compared to heat cured acrylic splint.
2.	Fisher's exact test	Fisher's exact test is used for small samples or when the expected cell frequency is <5 subjects	-
3.	McNemar test	Similar to Fischer exact test but for paired samples	-
4.	Mann Whitney U test (Wilcoxon's rank sum test)	It is a alternative to student 't' test & requires at least ordinal or nominal measurement	Evaluation of subgingival plaque by Plaque index in pregnant and non pregnant women
5.	Wilcoxon's signed rank test	Test is used for paired comparison	Speech evaluation before and after insertion of denture.
6.	Kruskal Wallis test	To compare more than two unpaired samples	Quality assessment of colour stability of different bleaching techniques (4 techniques) on vital tooth.

Table 4: Examples of parametric and non parametric tests

S.No	Objective	Parametric test	Non parametric test
1.	To compare difference between two groups	Unpaired t test	Wilcoxon rank sum test (Mann Whitney U test)
2.	To test difference between paired observation	Paired t test	Wilcoxon signed rank test
3.	To compare difference between several groups	One way ANOVA	Kruskal Wallis test
4.	To compare group values on two variables	Two way ANOVA	Friedmann test
5.	To measure association between two variable	Pearson's correlation coefficient	Spearman's correlation coefficient

Table 5: Statistical tests for Qualitative Vs Quantitative data (Number of groups-2)"

S.No	Data type	Distribution and variance/SD	Statistical tests
1.	Unpaired	Normal distribution, equal variance	Unpaired t test
2.	Unpaired	Normal distribution, unequal variance	Welch's test
3.	Paired	Normal distribution	Paired t test
4.	Unpaired	Non normal distribution	Mann- Whitney U test (Wilcoxon rank sum test)
5.	Paired	Non normal distribution	Wilcoxon signed rank test

Table 6: Statistical tests for Qualitative Vs Quantitative data (Number of groups-3)

S.No	Data type	Distribution and variance/SD	Statistical tests
1.	Unpaired	Normal distribution, equal variance	One way ANOVA
2.	Unpaired	Normal distribution, unequal variance	Kruskal Wallis test
3.	Paired	Normal distribution	Repeated measures one way ANOVA
4.	Unpaired	Non normal distribution	Kruskal Wallis test
5.	Paired	Non normal distribution	Friedman test

Table 7: Types of correlation coefficient.

S.No	Data type	Correlation test	Example
1.	Ordinal	Spearman 's correlation	To correlate orthodontic treatment need and level of satisfaction of personal dental appearance among dental students using IOTN index and questionnaire
2.	Interval or ratio	Pearson's correlation	To estimate the correlations between the photographic and cephalometric variables by measuring angular and linear parameters

Table 8: Types of regression analysis and their examples

S.No	Type of regression analysis	Independent variable	Dependent variable	Examples
1.	Simple linear regression	1 continuous	1 continuous Or only two continuous	• Orthodontic force and ridge resorption • Nature and type of tooth movement
2.	Multiple Linear regression	2 continuous/ categorial	1 continuous	• Effect of Age , sex and race on IGF level • Effect of incisor displacements in four directions (retraction, advancement, intrusion, and extrusion) in root resorption
3.	Simple logistic regression	1 continuous or 1 categorial	1 categorial (binary)	• Tobacco chewing and oral cancer • Patient compliance in male and female • The relationship between overall oral health impact (OIDP) and adolescents' orthodontic treatment status • Habits and malocclusion
4.	Multiple logistic regression	2 or more categorial	1 categorial (binary)	• Wish and positive attitude towards orthodontic treatment with patient compliance • Craniofacial dimension, head posture, bite force and signs of TMD.

Correlation Analysis

Correlation used with two variables to determine a relationship or association. It does not distinguish between independent and dependent variables. Correlation is a measure of association between two variables. The variables are not designated as dependent or independent. The two most popular correlation coefficients are: Spearman's correlation coefficient and Pearson's correlation coefficient. When calculating a correlation coefficient for ordinal data, select Spearman's technique. For interval or ratio-type data, use Pearson's technique (table 7) The value of a correlation coefficient can vary from minus one to plus one. A minus one indicates a perfect negative correlation, while a plus one indicates a perfect positive correlation. A correlation of zero means there is no relationship between the two variables. When there is a negative correlation between two variables, as the value of one variable increases, the value of the other variable decreases, and vice versa.

Regression Analysis

Regression analysis is used when we want to predict a continuous dependent variable from a number of independent variables. If the dependent variable is dichotomous, then logistic regression should be used. If the dependent variable is dichotomous, then logistic regression should be used. The independent variables used in regression can be either continuous or dichotomous. Types of regression analysis (table 8)

Calculation of measurement error

The intraclass correlation coefficient (ICC) is very useful in assessing errors. There are other useful methods of measurement error, such as the Dahlberg formula and Bland-Altman method (graphical method) for continuous variables, or the Kappa coefficient for categorical variables.

CONCLUSION

Use of appropriate statistical test is utmost important. Without proper statistical analysis even a well conducted study is not able to conclude with concrete results. It is always better to consult a statistician for selecting proper statistical test.

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Source of Support: Nil **Conflict of interest: None declared**