

Variability of shear and microtensile bond strength tests to enamel and dentin

Variabilidade de testes de cisalhamento e microtração ao esmalte e à dentina

Abstract

Purpose: This study aimed to provide guidelines about the coefficient of variation (CV) of shear (SBS) and microtensile (μ TBS) bond strength to enamel and dentin.

Methods: A search of the English language peer-reviewed literature was conducted using the PubMed database from 2000 to 2009. Only bond strength studies (SBS and μ TBS) that have tested both enamel and dentin substrates were selected. The following information was gathered from the 103 papers selected: groups mean and standard deviation (SD), repetition number, and type of statistical analysis. The CV of each study was calculated by using its mean and SD values, the normality of shear and microtensile CV was analyzed using Shapiro-Wilk test, and a CV classification was established for each variable.

Results: According to the CV classification proposed, values below 10.3% and 11.3% could be considered low for shear bond strength to enamel and dentin, respectively; and values below 15.4% to enamel and 16.4% to dentin could be considered low for the microtensile test. Values higher than 46.8% and 62.1% (shear bond strength to enamel and dentin) and 45.9% and 45.5% (microtensile bond strength to enamel and dentin) showed a very high variability.

Conclusion: Such classification can be useful for future experiments on adhesive materials to estimate statistical power and data precision.

Key words: Tensile strength; shear strength; statistical analysis

Resumo

Objetivo: Este estudo se propôs a fornecer diretrizes sobre o coeficiente de variação (CV) de ensaios de resistência ao cisalhamento (SBS) e à microtração (μ TBS) em esmalte e dentina.

Metodologia: Uma busca de artigos publicados de 2000 a 2009 foi realizada na base de dados PubMed. Apenas estudos (SBS e μ TBS) que testaram esmalte e dentina foram considerados elegíveis. As seguintes informações foram coletadas dos 103 artigos selecionados: média e desvio-padrão (DP) dos grupos, número de repetições e análise estatística. O CV de cada estudo foi calculado utilizando-se média e DP, a normalidade dos CV de cada teste foi analisada pelo teste de Shapiro-Wilk e classificações para os CV foram estabelecidas.

Resultados: De acordo com a classificação proposta, valores menores que 10,3% e 11,3% são baixos para estudos de cisalhamento ao esmalte e dentina, respectivamente. Para estudos de microtração, baixa variabilidade é obtida com CV menores que 15,4% (esmalte) e 16,4% (dentina). Experimentos com CV maiores que 46,8% e 62,1% (cisalhamento no esmalte e dentina) e 45,9% e 45,5% (microtração no esmalte e na dentina) apresentam variabilidade muito alta.

Conclusão: Esta classificação pode ser útil para futuros experimentos em Odontologia adesiva para estimar o poder estatístico dos testes e a precisão dos dados.

Palavras-chave: Resistência à tração; resistência ao cisalhamento; análise estatística

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Introduction

The role of Statistics in scientific investigations includes not only performing data calculations but also assisting in planning and designing studies. Statistical methods allow the establishment of the optimal sample size and variability of studies and indicate the error probability on assuming some premisses. For these reasons, a researcher should understand some basic concepts and analytic methods in order to formulate appropriated conclusions.

The coefficient of variation (CV) is a statistical measure used to estimate the data variability in experimental results. Using this coefficient one can compare standard deviations and variances of distributions that have different mean values and/or use different units of measurement (1). Besides that, the CV can help to define the repetition number (n) to detect significant differences in a specific probability. Hence it can be helpful to estimate the study power (2,3). The coefficient of variation is a ratio of the value of the standard deviation relative to the value of the mean $[(s/x)*100]$, where s represents standard deviation, and x the mean (4). The numerical value represented by the CV is expressed in percentage, not in the units employed to measure the variable. The larger the CV computed for a variable, the greater the degree of variability on that variable (4).

Variables can present significant discrepancies in their CV, and a specific value can be considered high for a determined variable and low for another (5). Therefore, the CV classification of each experimental variable could allow researchers to determine the accuracy of experiments results and to compare their results with previous studies (2,6,7). Shear and microtensile bond strength are methods frequently used in Restorative Dentistry and Dental Materials studies (8-10). These tests allow comparisons between products and techniques. There are many published data about these variables presenting fairly adequate statistical analyses, but only few authors used the CV values in their analyses (11-14). The aim of this study was to analyze the variability of published studies on shear and microtensile bond strength to enamel and dentin and to propose a classification criteria based on CV.

Methods

A search of the English language peer-reviewed literature was completed using PubMed database, from the period of 2000 to 2009. Key words used for the electronic search were: shear, microtensile, micro-tensile, "micro tensile", enamel, and dentin. Papers that have not tested both enamel and dentin substrates were excluded from further evaluation. One hundred and three manuscripts were found; 39 studies used the microtensile test (μ TBS) and 64 used the shear bond strength (SBS) test.

Manuscripts involved *in vitro* experiments on shear and microtensile bond strength to tooth structure using different adhesive materials. Journals searched were: Acta Odontol Latinoam (2), Acta Odontol Scand (1), Am J Dent (12),

Biomed Mater Eng (1), Braz Dent J (1), Clin Oral Investig (1), Compend Contin Educ Dent (1), Dent Mater (15), Dent Mater J (4), Eur Arch Paediatr Dent (1), Eur J Oral Sci (3), Eur J Paediatr Dent (1) Gen Dent (2), Int J Paediatr Dent (1), J Adhes Dent (15), J Am Dent Assoc (1), J Biomater Res (4), J Clin Pediatr Dent (2), J Contemp Dent Pract (2), J Dent (7), J Dent Res (1), J Endod (1), J Esthet Rest Dent (2), J Mater Sci (1), J Oral Rehabil (1), J Prosthet Dent (2), Lasers Med Sci (1), Oper Dent (13), Pesqui Odontol Bras (1), Pract Proc Aesthet Dent (1), Quintessence Int (2).

Manuscripts were fully read and the following data were collected: presence of coefficient of variation (CV), repetition number (n), mean values and standard deviation (SD) per experimental group. On microtensile studies, specimens shape (trimmed or untrimmed) was recorded. Finally, the presence of statistical analysis and statistical tests employed were observed.

The coefficient of variation from each article was calculated using its mean and standard deviation. Then, the normality of shear and microtensile CV was analyzed using Shapiro-Wilk test, with the SAS 9.1 software program (SAS Institute, Cary, NC, USA).

The classification proposed for the coefficient of variation used the following criteria, where x represents the mean CV and s its standard deviation (2,7): Low: $CV*x-s$; Medium: $x-s < CV*x+s$; High: $x+s < CV*x+2s$; Very high: $CV > x+2s$.

Results

All studies evaluated presented statistical analysis and mentioned a dispersion statistics, mainly the standard deviation. The statistical tests most frequently employed on microtensile and shear investigations were the Analysis of Variance (ANOVA) and post-hoc tests for multiple comparisons among means. Non-parametric tests were also observed (Table 1).

Table 1. Statistical tests most frequently applied in studies on microtensile and shear bond strength to enamel and dentin substrates.

	Tests	N	%
Parametric	ANOVA	113	92
	Other (t-Student, Cox hazard model)	8	8
Post-hoc	Tukey	55	61
	Other (Sheffe, Duncan, Bonferroni, SNK, REGW, DSCF, Dunnett)	35	39
Non-parametric	Kruskal-Wallis	16	51
	Other (Wilcoxon, Mann-Whitney, Friedman)	14	62

The Shapiro-Wilk test indicated a normal distribution of microtensile and shear CV ($P > 0.05$). The mean and standard deviation of the CV from the microtensile studies on enamel and dentin substrates were 25.5 (10.2) and

26.1 (9.7), respectively. For the shear variable, mean CV values for enamel and dentin were 22.5 (12.2) and 28.2 (17.0), respectively. Using the calculated CV for each variable and substrate, a classification criteria was established (Table 2), and the CV values were distributed in a range of low, medium, high, and very high (Table 3). Medium CV was the most commonly noted on microtensile and shear studies, regardless of the substrate evaluated.

From the other information gathered from the selected studies, it could be observed that the mean repetition number (n) for microtensile studies was 5, while 11 was the mean n for shear studies. The non-trimming technique was used on 53% of the microtensile studies, and the trimming technique (hour-glass or dumbbell-bell) was selected on the other 47%. The classification of studies' CV in accordance to the specimens shape is shown on Table 4. A greater number of low CV was detected on microtensile studies using the non-trimming technique.

Table 2. Classification of the coefficient of variation (CV) in studies on microtensile (μ TBS) and shear (SBS) bond strength to enamel (E) and dentin (D).

	Classification of the coefficient of variation			
	Low	Medium	High	Very high
μ TBS-E	CV<15.4	15.4<CV<35.7	35.7<CV<45.9	CV>45.9
μ TBS-D	CV<16.4	16.4<CV<35.8	35.8<CV<45.5	CV>45.5
SBS-E	CV<10.3	10.3<CV<34.7	34.7<CV<46.8	CV>46.8
SBS-D	CV<11.3	11.3<CV<45.2	45.2<CV<62.1	CV>62.1

Table 3. Distribution (%) of the coefficient of variation (CV) in studies on microtensile (μ TBS) and shear (SBS) bond strength to enamel (E) and dentin (D).

	Distribution of the coefficient of variation				Total
	Low	Medium	High	Very high	
μ TBS-E	19	70	7	4	100%
μ TBS-D	22	56	22	0	100%
SBS-E	16	79	0	5	100%
SBS-D	11	74	11	5	100%

Table 4. Distribution (%) of the coefficient of variation (CV) in studies on microtensile (μ TBS) bond strength to enamel (E) and dentin (D) using the non-trimming and trimming technique.

Technique	Distribution of the coefficient of variation				Total
	Low	Medium	High	Very high	
Non-trimmed					
μ TBS-E	29	57	7	7	100%
μ TBS-D	43	36	21	0	100%
Trimmed					
μ TBS-E	8	84	8	0	100%
μ TBS-D	0	77	0	23	100%

Discussion

Statistics knowledge is fundamental for the planning, execution, and discussion of experimental results (15). In a similar way, the correct data interpretation and assessment of study precision are mandatory for the clinical application of research results. According to the findings of the present study, the statistical methods most frequently observed in shear and microtensile investigations were parametric tests: Analysis of Variance (ANOVA) and multiple comparison (post-hoc) tests. Shear and microtensile are quantitative variables; quantitative data that are normally distributed are also called parametric data because data distribution can be described by the mean and standard deviation (15). Thus, parametric tests are the most appropriate tests to determine mathematical differences between groups, and shear and microtensile studies seem to be in agreement to statistical concepts.

In some manuscripts, the application of nonparametric methodologies was observed. When quantitative data are not normally distributed, they cannot be adequately described by just the mean and standard deviation because data distribution does not follow a bell-shaped curve. Therefore, it is unsuitable to use a parametric test on these types of data (15), and nonparametric analysis would be more appropriate for quantitative data that are not normally distributed.

An important issue frequently overlooked in dental research is sample size and study power (16,17). The power of a hypothesis test relates to the probability of rejecting the null hypothesis when the alternative hypothesis is true (16). The power of a study depends on several factors, but as a general rule higher power is achieved by increasing the sample size (16). According to this investigation, the mean repetition number of shear bond strength studies is approximately the double used for microtensile investigations. This finding might be explained by the greater variability and lack of standardization of shear testing methods (9).

As previously stated, a known CV can help to calculate the most adequate sample size to obtain accurate results (3). The present study suggested an adaptation of a CV classification for two quantitative variables frequently used in research on adhesive materials: shear and microtensile bond strength (7). According to the classification proposed, a CV lower than 10.3% and 11.3% indicate low variability for shear studies on enamel and dentin, respectively. For microtensile studies, low variability is depicted by a CV lower than 15.4% on enamel and 16.4% on dentin. On the other hand, experiments with CV values higher than 46.8% and 62.1% (shear on enamel and dentin) and 45.9% and 45.5% (microtensile on enamel and dentin) present a very high variability. These values are slightly different from the CV of 50% described by the ISO 11405 as a large variation (18). Difference between treatments may not be detected in experiments with high CV values because of either the heterogeneity of experimental material or the method of conducting the research. Thus, if greater variability is expected, researchers might consider using a larger repetition number.

For microtensile investigations, it should be highlighted that the specimen shape might influence the variability of bond strength. It was noted that a greater number of low CV was detected on studies using the non-trimming technique. The trimming method may weaken the adhesive bond due to an extra-stress at the interface and compromise structural integrity in trimmed specimens (19). These findings might justify the number of low CV on microtensile using the trimming technique.

In medical studies, the coefficient of variation has been used as a measure of precision and repeatability of data (1,20). However, from the data gathered in the present study, it could be observed that the CV is rarely discussed in dental research, and only few authors appear to understand its importance indicating the coefficient of variation in their experiments.

Conclusions

Within the limitations of the present study, the following conclusions could be drawn:

- Using the present CV classification, researchers would be able to compare their results and determine which level of variability their studies have (low, medium, high and very high).
- Bond strength tests show different CV range, which justify larger sample size for shear investigations than for microtensile tests.
- The substrate (enamel and dentin) or specimen shape (for microtensile studies) might affect CV classification.

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