Cyanoacrylate Tissue Adhesive: Evaluation of Vickers Microhardness, Roughness, Solubility And Microbiological Effects

Adesivo tecidual à base de Cianoacrilato: Microdureza Vickers, rugosidade, solubilidade e efeitos microbiológicos

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ABSTRACT

Objectives: This study performed laboratory tests to evaluate the microhardness, roughness, solubility and microbiological effects of this material. Methods: Cyanoacrylate specimens measures 1 centimeter wide, 2 centimeter long and 4 to 7 mm high were prepared and divided into 4 groups (n = 12): G1: sterile saline solution; G2: nutrient broth without microorganism; G3: nutrient broth with Candida albicans and G4: nutrient broth with Staphylococcus aureus. The specimens were submitted to Vickers microhardness test, roughness, solubility and microbiological effects. Statistical analysis to evaluate before and after immersion was performed by the paired T-test or Wilcoxon. To verify difference in weight, Friedman’s test and ANOVA were used. To compare the microhardness and roughness between the groups, the ANOVA and Kruskal-Wallis tests were used. Results: There was a significant difference in weight in the three times evaluated in all groups, a significant increase in microhardness and roughness. There was no significant difference between the groups, after immersion, when microhardness and roughness were compared. Then, microhardness and roughness increased after submersion in the four groups. Conclusion: There was no visibly microbial aggregation in the presence of microorganism in cyanocrilate specimens. Keywords: cyanoacrylate, hardness, solubility, tissue adhesive, surgery.

RESUMO

Objetivos: Este estudo realizou testes de laboratório para avaliar a microdureza, rugosidade, solubilidade e efeitos microbiológicos deste material. Material e Métodos: espécimes de cianoacrilato medindo 1 centímetro de largura, 2 centímetros de comprimento e 4 a 7 mm de altura foram preparados e divididos em 4 grupos (n = 12): G1: solução salina estéril; G2: caldo nutritivo sem microrganismo; G3: caldo nutritivo com Candida albicans e G4: caldo nutritivo com Staphylococcus aureus. Os corpos-de-prova foram submetidos aos testes de microdureza Vickers, rugosidade, solubilidade e efeitos microbiológicos. A análise estatística para avaliação antes e após a imersão foi realizada pelo teste T pareado ou Wilcoxon. Para verificar a diferença de peso, foram utilizados o teste de Friedman e ANOVA. Para comparar a microdureza e rugosidade entre os grupos, foram utilizados os testes ANOVA e Kruskal-Wallis. Resultados: Houve diferença significativa no peso nas três vezes avaliadas em todos os grupos, aumento significativo na microdureza e rugosidade. Não houve diferença significativa entre os grupos, após a imersão, quando comparadas microdureza e rugosidade. Em seguida, a microdureza e a rugosidade aumentaram após a submersão nos quatro grupos. Conclusão: Não houve agregação visivelmente microbiana na presença do microrganismo nas amostras de cianocrilato. Palavras-chave: cianoacrilato, dureza, solubilidade, adesivo tecidual, cirurgia.
INTRODUCTION

The closure of an injury is part of the surgical act. The purpose of restoring a wound or incision is to join the edges of the tissue so that the natural healing process occurs.\(^1\) Periodontal aesthetics have been considerably valued.\(^2\) In order to achieve adequate tissue repair, which involves the epithelium and the conjunctiva, it is necessary for the organism to have adequate local and general circumstances.\(^3\) Another desirable factor in a procedure for joining the surgical edges is that it should be fast, easy to perform, inexpensive.\(^4\)\(^-\)\(^7\) Materials used in surgical edge join procedures include conventional sutures and tissue adhesives (biological or synthetic cyanoacrylate).\(^1,\)\(^8\)\(^-\)\(^9\)

Cyanoacrylate (CA) was discovered in 1949 and recognized by Coover's adhesive property in 1959.\(^1,\)\(^10\) Since the first favorable result of the medical use of CA adhesive in the 1960s as a suture and local hemostatic agent in the wounds of War Vietnam, its use in tissue wound synthesis has been expanded to other areas of health, including dentistry.\(^11\)\(^-\)\(^12\)

The evolution of technology has led to the development of biodegradable bonding materials that are more compatible with living tissues.\(^13\) In this way, cyanoacrylates have been applied to the union of tissues, thus eliminating the phases of suture placement and removal.\(^10,\)\(^14\)\(^-\)\(^17\) One of the advantages of its use is the fact that this adhesive stabilizes and fixes and promotes hemostasis.\(^11\) Furthermore, they exhibit bacteriostatic properties, exhibit rapid polymerization and excellent tensile strength.\(^1,\)\(^12,\)\(^15,\)\(^18\)\(^-\)\(^20\)

The aim of the present study was to perform laboratory tests to evaluate the Vickers microhardness, roughness, solubility and microbiological effects of cyanoacrylate for surgical edge closure.

METHODS

Before the experiments were carried out, a gypsum matrix was prepared to obtain forty eight specimens of the ethylcyanoacrylate adhesive. The gypsum matrix was prepared as follows: 05 slides of microscope glass (26x76mm) were selected for each matrix. The stone type III gypsum was placed on the blade and removed after its total prey, in this way flat and smooth surfaces were obtained for the subsequent placement of the adhesive. After CA placement, we expected 07 days at room temperature with the variation of days in minimum of 14° C and maximum of 27° C. After the total polymerization of the CA, to separate it from the gypsum was used gypsum trimmer. Sequentially, the adhesive was cut with steel disc to obtain the following dimensions in each specimen: 1cm wide by 2cm long and height ranging from 4-7mm. Subsequently, the specimens were polished in a polystyrene using cotton cloth wheel with mass under light pressure so that there was no overheating of the adhesive material.

The Vickers microhardness test was performed using Panantec ATMI digital microdurometer, with 100g load applied for 10 s. The rugosity test was performed using the time group INC rugosimeter.

To evaluate the Vickers microhardness, roughness, solubility and microbiological effects, 48 test tubes were selected for submersion of the CA fixed in dental floss, separated into four groups of 12, being:

- 1st group: sterile saline;
- 2nd group: nutrient broth without microorganism;
- 3rd group: nutrient broth with Candida albicans;
- 4th group: nutrient broth with Staphylococcus aureus.

The evaluation of Vickers microhardness and roughness was performed before and after submersion in the four groups mentioned above. Previously, the specimens were weighed and sterilized in a vertical unidirectional flow hood (FUV 12). After placing the CA in the tubes they were stored in an oven at 37° C for 7 days and then weighed and evaluated again for Vickers microhardness and roughness.

The data collected were analyzed by SPSS software (Statistical Package for
Social Sciences, IBM Inc., USA) version 25. Descriptive statistics analyzes were performed to obtain mean and standard deviation. The normality of the data was verified by the Shapiro-Wilk test. To verify if there was a significant difference of microhardness and roughness before and 7 days after immersion, the results were submitted to the paired T test or Wilcoxon when pertinent. In order to verify if there was difference in weight at the different evaluation times, the data were submitted to the Friedman test and ANOVA of repeated measures, with post-hoc Wilcoxon and Bonferroni, respectively. To compare the microhardness and roughness between the groups, the ANOVA and Kruskal-Wallis tests were used. The significance level of 95% was adopted (p < 0.05).

**Results**

Table 1 presents the descriptive analysis of the weight, microhardness and rugosity of the specimens according to the group and time of evaluation, to obtain the mean and standard deviation of the following groups: sterile saline, nutrient broth without microorganism, nutrient broth with Candida albicans and nutrient broth with Staphylococcus aureus.

| Variable               | Mean   | Standard Deviation (SD) |
|------------------------|--------|-------------------------|
| **Sterile saline**     |        |                         |
| Weight before          | 1,802  | 0,385                   |
| Immediate weight       | 1,846  | 0,360                   |
| Weight after 7 days    | 1,802  | 0,385                   |
| Microhardness before   | 10,142 | 1,648                   |
| Microhardness after 7 days | 13,846 | 2,579                  |
| Roughness before       | 0,825  | 0,465                   |
| Roughness after 7 days | 1,568  | 1,350                   |
| **Nutrient Broth**     |        |                         |
| Weight before          | 1,594  | 0,189                   |
| Immediate weight       | 1,604  | 0,189                   |
| Weight after 7 days    | 1,594  | 0,189                   |
| Microhardness before   | 12,293 | 3,005                   |
| Microhardness after 7 days | 13,494 | 1,942                  |
| Roughness before       | 1,111  | 0,404                   |
| Roughness after 7 days | 1,950  | 1,200                   |
| **Candida albicans**   |        |                         |
| Weight before          | 1,483  | 0,208                   |
| Immediate weight       | 1,491  | 0,210                   |
| Weight after 7 days    | 1,483  | 0,208                   |
| Microhardness before   | 12,057 | 2,833                   |
| Microhardness after 7 days | 13,603 | 1,917                  |
| Roughness before       | 1,075  | 0,562                   |
| Roughness after 7 days | 2,112  | 1,289                   |
| **Staphylococcus aureus** |   |                         |
| Weight before          | 1,490  | 0,218                   |
| Immediate weight       | 1,502  | 0,220                   |
| Weight after 7 days    | 1,492  | 0,220                   |
| Microhardness before   | 10,819 | 1,873                   |
| Microhardness after 7 days | 14,474 | 1,983                  |
| Roughness before       | 1,031  | 0,391                   |
| Roughness after 7 days | 1,924  | 1,007                   |
Table 2 shows the comparison of the weight of the specimens according to the group. It was observed that there was a statistically significant difference of the weight in the three times evaluated in all the groups. Through the post-hoc test, it was verified in all the groups that this difference is between the immediate evaluation, evaluation before and 7 days after.

### Table 2. Comparison of test weight according to group.

| Weight (g)          | Group (G)       | Before (G1) | Immediate (G2) | 7 days (G3) | p         | Post-hoc test          |
|---------------------|-----------------|-------------|----------------|-------------|-----------|-------------------------|
| Sterile saline      |                 | 1,802 (0,385) | 1,846 (0,360) | 1,802 (0,385) | <0,001*  | G1xG2: 0,002            |
|                     |                 |             |                |             |           |                         | G1xG3: 0,999            |
|                     |                 |             |                |             |           |                         | G2xG3: 0,002            |
| Nutrient Broth      |                 | 1,594 (0,189) | 1,604 (0,189) | 1,594 (0,189) | <0,001** | G1xG2: 0,001            |
|                     |                 |             |                |             |           |                         | G1xG3: 0,999            |
|                     |                 |             |                |             |           |                         | G2xG3: 0,001            |
| Candida albicans    |                 | 1,483 (0,208) | 1,491 (0,210) | 1,483 (0,208) | <0,001** | G1xG2: 0,002            |
|                     |                 |             |                |             |           |                         | G1xG3: 0,999            |
|                     |                 |             |                |             |           |                         | G2xG3: 0,002            |
| Staphylococcus aureus|                | 1,490 (0,218) | 1,502 (0,220) | 1,492 (0,220) | <0,001** | G1xG2: <0,001           |
|                     |                 |             |                |             |           |                         | G1xG3: 0,498            |
|                     |                 |             |                |             |           |                         | G2xG3: <0,001            |

* Friedman’s test, post-hoc Wilcoxon. ** ANOVA of repeated measures, post-hoc Bonferroni

In table 3 it is possible to evaluate the comparison of microhardness before and after immersion, according to the group. It was observed that there was a statistically significant increase of microhardness in the sterile saline, Candida albicans and Staphylococcus aureus groups. However, the second group, nutrient broth, obtained many losses and there was no significant difference. Possibly, this low n led to non-statistical significance.

### Table 3. Comparison of the microhardness before and after immersion, according to the group.

| Microhardness (HV) | Group           | Before       | 7 days       | p*            |
|--------------------|-----------------|--------------|--------------|---------------|
| Sterile saline     |                 | 10,142 (1,648)| 13,846 (2,579)| 0,001         |
| Nutrient Broth     |                 | 12,293 (3,005)| 13,494 (1,942)| 0,731         |
| Candida albicans   |                 | 12,057 (2,833)| 13,603 (1,917)| 0,038         |
| Staphylococcus aureus |               | 10,819 (1,873)| 14,474 (1,983)| <0,001        |
|                    | * Paired T-Test |              |              |               |

* Paired T-Test
Table 4 shows the comparison of roughness before and after immersion, according to the group. It was noticed that there was a statistically significant increase of the roughness in all the groups.

Table 4. Comparison of roughness before and after immersion, according to the group.

| Group                | Before         | 7 days         | p*   |
|----------------------|----------------|----------------|------|
| Sterile saline       | 0.825 (0.465)  | 1.568 (1.350)  | 0.015*|
| Nutrient Broth       | 1.111 (0.404)  | 1.950 (1.200)  | 0.012*|
| Candida albicans     | 1.075 (0.562)  | 2.112 (1.289)  | 0.006**|
| Staphylococcus aureus| 1.031 (0.391)  | 1.924 (1.007)  | 0.010*|

* Wilcoxon test. ** Paired T-Test

Table 5 expresses the comparison of microhardness between groups, after immersion. It was verified that there was no statistically significant difference between the groups when microhardness was compared.

Table 5. Comparison of microhardness between groups after immersion.

| Group                | Microhardness (HV) | p*   |
|----------------------|--------------------|------|
| Sterile saline       | 13,846 (2,579)     |      |
| Nutrient Broth       | 13,494 (1,942)     | 0.728|
| Candida albicans     | 13,603 (1,917)     |      |
| Staphylococcus aureus| 14,474 (1,983)     |      |

* ANOVA One-Way

Table 6 shows that there was no statistically significant difference of the roughness in the comparison between the groups, after immersion.

Table 6. Comparison of roughness between groups after immersion.

| Group                | Roughness (μm) | p*   |
|----------------------|----------------|------|
| Sterile saline       | 1.568 (1.350)  |      |
| Nutrient Broth       | 1.950 (1.200)  | 0.288|
| Candida albicans     | 2.112 (1.289)  |      |
| Staphylococcus aureus| 1.924 (1.007)  |      |

Kruskal-Wallis Test
**Discussion**

Among the surgical edge coaptation materials is the synthetic cyanoacrylate (CA) adhesive.\(^{15,19,20}\) Unlike traditional white glues, which depend on evaporation to form their bonds, cyanoacrylate generates its own heat. Polymerization of the material occurs rapidly, ranging from 10 to 15 seconds. It is noted that this material is non-absorbable and is worn from the surface of the mucosa between 7 and 10 days after its use.\(^{10}\) It acts as a hemostatic agent, exhibits bacteriostatic properties, exhibits rapid polymerization and excellent tensile strength.\(^{1,18,19}\)

This study evaluated the Vickers microhardness of ethylcyanoacrylate. by definition, hardness is the ability of a material to withstand hard tip penetration and is directly proportional to the mechanical strength and wear resistance of a material. The microhardness is a nondestructive and specifically localized laboratory test, providing data of the distribution of the properties of the studied material.\(^{21}\)

It was observed that there was an increase in microhardness after submergence in the groups of sterile saline, nutrient broth without microorganism, nutrient broth with *Staphylococcus aureus* and nutrient broth with *Candida albicans*. The paired T-test showed that there was a statistically significant difference in the groups compared to the different evaluation times before and 7 days after submersion in the groups previously mentioned, except in the nutrient broth group. However, as seen by the One-Way ANOVA test, there was no significant statistical difference between the groups when compared to each other, thus showing that the temperature at 37°C and humidity were the common exposure factor of all groups to increase the resistance of this group material.

It is important to emphasize that weight should not be a parameter to evaluate the solubility and degradation of the material, as it was noticed that the specimens increased their weight during the period in which they were submerged in the test tubes, however 07 days after their withdrawal they returned to their original weight before being placed in the tubes.

However, the roughness test showed to be more sensitive for evaluation of solubility and degradation, due to the fact that the test specimens increased the roughness. Seen through the Wilcoxon test. and paired T test showed a statistically significant difference in the groups evaluated before and after submersion in the groups. When comparing the roughness of the groups between them, according to the Kruskal-Wallis test there is no significant statistical difference.

It is important to emphasize that weight should not be a parameter to evaluate the solubility and degradation of the material, as it was noticed that the specimens increased their weight during the period in which they were submerged in the test tubes, however 07 days after their withdrawal they returned to their original weight before being placed in the tubes.

In addition, it is interesting to note that there was clearly no bacterial and fungal aggregation in the cyanoacrylate body, but it was possible to observe growth of microbial plaque in dental floss where the body was fixed inside the test tubes in the groups containing *Staphylococcus aureus* and *Candida albicans*, perceptibly presenting the characteristic of this material to be antimicrobial. However, other studies are needed to evaluate the formation of the microbial biofilm on this material.

**Conclusion**

Based on the results, it is concluded that the synthetic ethylcyanoacrylate adhesive used for coaptation of surgical edges has improved resistance properties in the temperature increase. In addition, the weight should not be an instrument to evaluate the solubility and degradation, but the roughness test that has been shown to be more sensitive. In addition, there was no visible microbial aggregation in the presence of microorganism in the CA test specimens. However, further studies to evaluate these properties need to be performed for further evaluation.
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Disclosure statement

The authors declare no conflict of interest.

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Submetido em: 16-11-2020
Aceito em: 21-12-2021