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Comparing scalpel cut strength and depth on porcine gingival tissues

Comparación de fuerzas de corte del escalpelo y profundidad en tejidos gingivales porcinos

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ABSTRACT

Keywords: Scapel; Cutting effort; Incision depth; Rheology

The composition of gums confers some physical characteristics on them that make them resistant to mechanical stimulation. The objective of the study is to compare the difference between the utilized forces when performing cuts in the anterior and posterior sections of porcine gingival tissue, measuring its depth. A comparative descriptive study is performed with a non-probability convenience sampling; sectioned pig mandibles were used. The experimental trials are performed with an EZ-S SHIMADZU texture analyzer. All of the samples were submitted to a vertical shear force to identify the force level used to perform the incision and its depth. The necessary force to perform a cut in porcine gingival tissue is evaluated, comparing the posterior section (39.3571 Newton and 2.160 mm) with the anterior section (37.8424 Newton and 1.747 mm), as well as the depth of said cut, showing a statistical difference ($p=0.022$; $p<0.59$). Regarding force, no statistically significant difference was found. In the analyzed samples in which the shear force in the posterior and anterior sections were compared, no difference was found in both groups. As for cut depth, it was greater in the posterior section than in the anterior one.

RESUMEN

Palabras clave: bisturí; esfuerzo de corte; profundidad de incisión; reología.

La composición de las encías le confieren algunas características físicas que las hacen resistentes al estímulo mecánico. El objetivo del estudio fue comparar la diferencia de fuerzas utilizadas al realizar cortes en las secciones anterior y posterior del tejido gingival porcino, a la vez que se mide la profundidad del tejido. Se realizó un estudio descriptivo comparativo con un muestreo de conveniencia no probabilístico y se utilizaron mandíbulas de cerdo seccionadas. Los ensayos experimentales se realizaron en un analizador de textura EZ-S SHIMADZU. Todas las muestras se sometieron a una fuerza de corte vertical, por lo que se identificó el nivel de fuerza utilizado para realizar la incisión y su profundidad. Se evaluó la fuerza necesaria para realizar un corte en el tejido gingival porcino y se comparó la sección posterior con la anterior, al igual que la profundidad de dicho corte, lo que mostró una diferencia estadística ($p=0{,}022$; $p<0{,}59$). Con respecto a la fuerza, no se encontraron diferencias estadísticamente significativas. En las muestras analizadas en las que se comparó la fuerza de corte en la sección posterior y anterior, no se encontraron diferencias en ambos grupos; en cuanto a la profundidad de corte, esta fue mayor en la sección posterior que en la anterior.

INTRODUCTION

The oral cavity possesses an anatomy that is rich in muscle and mucous tissue, which offers an operator certain resistance when performing an incision in surgery. The close proximity of a great area of the oral mucosa to the subjacent maxillary bone is one of the modifying factors in the surgical management of lesions located in different tissues of the oral cavity[1].

Rheology is the science that studies the complex fluid response to two principal parameters: effort and deformation (flux)[2]. Due to the characteristics shown by the gum, rheological studies can be applied. There are models based on the microstructure of the soft tissue that allow to predict the response of these tissues to mechanical stimulus[3]. This confirms the necessity of knowing the rheological behavior of tissues to determine the appropriate manipulation when performing any invasive procedure that involves an injury[4].

The scalpel is an essential element in surgical treatments in the oral cavity and has an evolution and extensive historical use in various surgical fields. Within the dental literature there are relatively few scientific works that describe their behavior when applying rheology principles, as proposed by Carter et al. in 2005[5,6].The physical alterations that occur in its shape, product of its use, and thus prevent possible alterations in the structure of oral tissues are produced by making successive incisions in an area of an individual in the surgical act[6], by the deformation on the cutting surface of the leaves that must be expected and what happens[6] .This situation can eventually cause greater damage to the incised tissues, with alterations that will not be studied in the present article. This in turn leads to longer periods of healing and delayed recovery.

The components of the gum include epithelial and connective tissues, together with the periodontium, the periodontal ligament, the alveolar bone and root cement. Its composition grants itself physical characteristics that turn it resistant to mechanical stimulus and give it the particular aspects that are normally seen in a healthy gum[7].

In 2014, Kondo et al[8], conducted a comparative study to evaluate the properties of epithelial cells in the oral mucosa of six different animal species. They state that, although there are differences in sizes and the possibility of using oral tissues as substitutes, oral epithelia in human and swine gum were relatively thicker than the epithelia in other species, and that they were considerably similar in histological and morphological terms.

The objective of this study is to compare the difference between used forces when performing cuts in the anterior and posterior sections of porcine gingival tissue. This action produces its deformation in relation with its thickness and depth of the cut.

MATERIALS AND METHODS

Type of study

The research carried out was of a descriptive comparative type. Using such a model of experimentation, jaws of ex vivo pigs from local markets of the city of Cartagena, Colombia. It should be remarked that the pigs were not slaughtered for the development of this research. They were sacrificed for regular consumption.

Population and sample

Sample consisted of 30 porcine bone portions with the presence of gingival covering of the anterior section and 30 porcine bone portions with the presence of gingival covering of the posterior section. They were submitted to vertical shear forces that were measured with a Shimadsu texture analyzer (model EZ-S, serial number 346-54909-33). The force used to perform the incision was measured both in the anterior and posterior sections. The depth of each cut was also measured with the same equipment. A non-probability convenience sampling was carried out. As selection criteria, porcine bone portions with the presence of gingival covering and collected in the last 24 hours were taken to keep the tissue in an unaltered anatomic condition (Figure 1).

Figure 1. Mounting in the texture analyzer to measure shear force in a pig mandible (lateral view).

Materials and procedures

The employed materials were porcine gingival tissue, scalpel blades Elite® Nº15, a texture analyzer, a periodontal probe, a digital thermometer and an ice container. Samples were taken from the tissues that met the inclusion criteria, sectioning the pig mandibles in 2 cm x 2 cm cuts from the posterior area, and then stored in an ice container at 4 °C–8 °C while they were transported to the laboratory. The 2 cm x 2 cm samples were placed in the texture analyzer with a maximum capacity range of 500 Newton, which is a range of work in the texturometer, where they were submitted to a compression force in which the scalpel blade penetrated and cut the tissue. - Samples were divided into two groups: Group 1 contains 30 samples from the posterior area and Group 2 contains 30 samples from the anterior area of gingival tissue.

The scalpel blade cut and penetrated the tissue until the blade touched the bone structure in one go For each cut performed, the blade was changed. The strength that the machine needed to penetrate vertically at a 90° angles was monitored and then the cut was measured with a periodontal probe to estimate the depth of penetration in different sections of the mandible. Table 1 reports all of the measures showed by the texture analyzer, regarding the utilized force in both the anterior and posterior areas when performing the cuts, as well as the depth of penetration estimated with the periodontal probe in each sample.

Statistical analysis

Normality tests such as the Shapiro-Wilk test were performed on the data of both groups (Group 1: samples from the posterior area; Group 2: samples from the anterior area) The, which were stored in a matrix table created in Microsoft Excel for Windows 8. This table contained every pieced of data thrown by the texture analyzer regarding the exerted pressure when performing each cut. Then they were exported to the SPSS Statistic v22 for Windows.

The used statistics for the force variable was the Student's T test for independent samples considering confidence intervals of 95%. Besides, for the differences, significance levels lower than p=0.05 were be considered for rejection alpha errors. For the depth variables, the Mann-Whitney U test and the non-parametric version of the Student's T test for equal sized samples were performed having as null hypothesis that the starting distributions of both groups is the same, and as alternative hypothesis that the value of one of the samples tends to exceed those of the other samples. With a 95% confidence level, besides for the differences will also be considered significance levels lower than p=0.05 for rejection alpha errors. Descriptive statistics were previously applied (measures of central tendency and dispersion) to the groups and the included for the thickness of the gingival tissue in the anterior and posterior areas.

Bioethical considerations

For bioethical considerations, authors declare that they have complied with Resolution 008430 of 1993 by the Health Ministry of the Republic of Colombia.

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RESULTS

The normal probability plot for the force variable in the anterior and posterior areas shows good adjustment of residuals to normality since the points are quite proximate to the diagonal; therefore, the normality hypothesis does not present any problems (Figure 2).

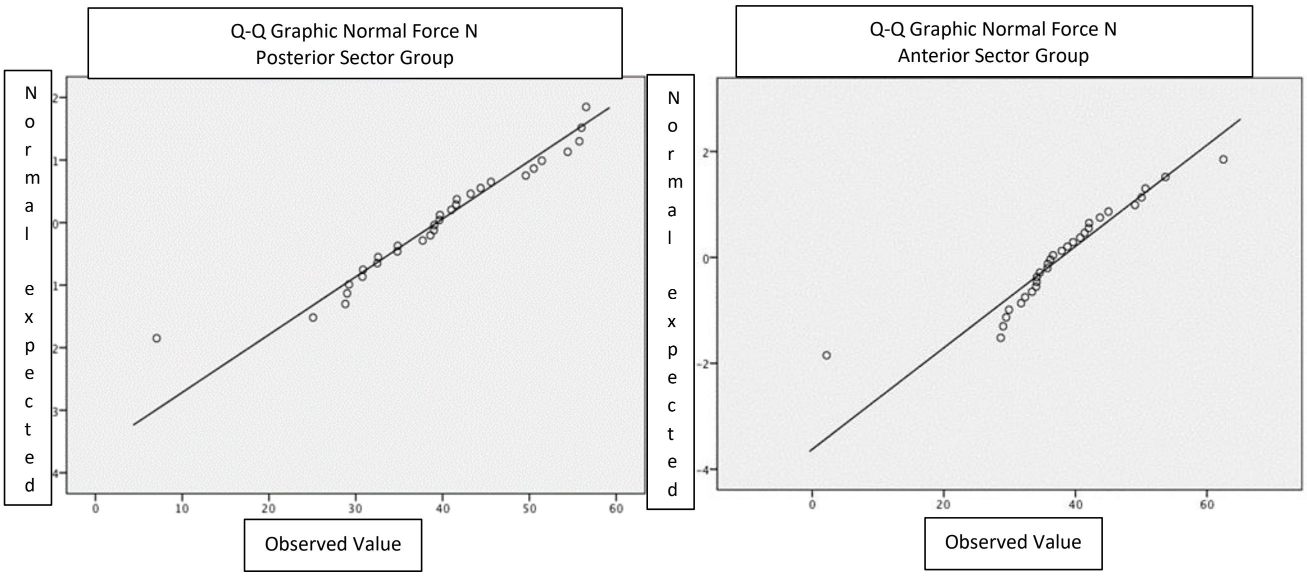

Figure 2. Data distribution is showed all along a straight line to determine its normality. All forces have normal distribution.

Descriptive statistics analysis of each group

An analysis of descriptive statistics was performed on the results, which can be seen in Tables 1 and 2.

Table 1. Descriptive statistics of Group 1. Porcine bone portion with gingival tissue covering in the posterior area.

Statistical parameter	Force (Newton)	Depth (mm)
Mean	39.3571	2.160
Median	39.3350	2.000
Standard deviation	10.8127	0.83006
Minimum	7.05	1.0
Maximum	56.54	4.0
Range	49.49	3.0

Intergroup analysis

In the analysis of the force variable that was carried out through the Student's T test, the means and confidence intervals from both sample groups were compared, which generated a P value of 0.583 (greater than 0.05). Therefore, the null hypothesis was accepted, indicating that there is no significant difference between the force applied to perform an incision in the posterior area and the anterior area of porcine gingival tissue (Table 3).

Table 2. Descriptive statistics of Group 2. Porcine bone portion with gingival tissue covering in the anterior area.

Statistical parameter	Force (Newton)	Depth (mm)
Mean	37.8424	1.747
Median	36.3950	1.700
Standard deviation	10.4455	0.8473
Minimum	2.18	1.0
Maximum	62.50	4.0
Range	60.32	3.0

Regarding the analysis of the depth variable, a Mann-Whitney U test was carried out since it did not have a normal distribution, having as a null hypothesis that depth distribution (mm) is the same between both groups. The obtained result was p=0.022, (lower than 0.05), leading us to reject the null hypothesis (Table 4). The cuts of the samples from Group 1 are significantly deeper those on the samples from Group 2.

Table 3. Results of Student's T test with variable force.

T test for equal means				
Significance	Mean difference	Standard error for the difference	95 % confidence interval for the difference	
			Lower	Higher
0.583	1.51467	2.74484	-3.97972	7.00905

Table 4. Results of hypothesis testing. Mann-Whitney U test.

Null hypothesis	Test	Sig	Decision
Force distribution (N) is equal between group categories.	Mann-Whitney U test of independent samples	0.515	Accept null hypothesis.
Depth distribution (mm) is equal between group categories.	Mann-Whitney U test of independent samples	0.022	Reject null hypothesis.

Asymptotic significances are shown. Significance level is 0.05.

DISCUSSION

The present study results from the need to evaluate and compare measures of force and depth in porcine gingival tissue with the purpose of advancing in the area of manipulation of this kind of soft tissue. The histological components of the gum, such as elastin fibers, allow it to endure forces that deform the tissue, regardless of the direction in which the force is being applied, while collagen fibers help to resist forces depending on the direction that force is being applied9. These properties account for the behavior of the gum to certain stimulus such as the force applied during a cut performed with a scalpel blade. Most of the experimental studies in soft tissue cuts are based on physical and geometrical models that strive to simulate the physical behavior of the tissue and explain how the internal and external forces change the properties of the tissue; however, just as this study in general, they do not further explain the physics behind the cut (such as the energy exchange)10 but the overall observed result, such as force readings or tissue elasticity when cutting11.

A total of 60 samples, 30 from the anterior section and 30 from the posterior section, were evaluated.

Samples were taken from pig mandibles within 24 hours of being slaughtered, contrary to what was reported by Chanthasopeephan12 who took porcine tissue two hours after the slaughter. The equipment utilized for force measuring was a Shimadzu EZ-D texture analyzer which provided readings that were digitalized in a computer. Some authors have implemented robotic technology with the incorporation of a scalpel blade and a digital camera, while the system is controlled from a computer. This equipment is even more sensitive to force readings, allowing to evaluate the exact moment of deformation, rupture and cut in the tissue13. However, it is important to highlight that in the present study the Shimadzu EZ-D texture analyzer was chosen since it allows to simulate the strength that an operator applies on the tissue and the trial is performed easily and rapidly.

In this study, it was found that generally there are no significant differences between the used force when cutting porcine gingival tissue in both the anterior and posterior sections, taking into account that during the procedure the angulation was always 90°. Other studies show that, for a determined cut velocity, resistance to deformation diminishes as the cutting angle varies from 90° to 45°, while for a determined cutting angle, resistance to deformation diminishes with an increase in cutting velocity12. The average applied force when cutting was 39.35 N for the posterior section and 37.84 N for the anterior section and, even though there were no statistically significant differences between both groups, these results are different from those by Ramachandra et al14 who reported50 gf, the recommendable force for probing at the time of clinical exploration. Caton et al15 and Al Shayeb et al16 also referred to this force value for probing and calibration of clinics when doing periodontal examinations. Even when the numbers are far from the ones found in this study, it should be considered that, during the probing, we were not looking for tissue deformation and rupture but rather its minimal lesion.

In terms of cut depth versus gum thickness, statistically significant differences were found, showing that these cuts were deeper in the posterior section than in the anterior section. The average depth found was 2.1 mm and 1.7 mm respectively, coinciding with Botero17 who, in his study on periodontal biotypes, mentioned that gum thickness increases as the tooth is localized in a more posterior position. Furthermore, Kan et al18 report that gum thickness is 1.6 ± 0.27 mm, regardless of the chosen section of the maxillary. It should be considered that both studies were performed in human beings and not in porcine tissue.

Authors such as Sa et al. in 201619 studied oral tissues from different animal species, such as dog, pig, rat, rabbit, and made morphological and histological comparisons. They report that many similarities may be detected between histological aspects of these species and humans. They also mention that it is possible to detect comparable results in the ability of keratinization, with similar length of rete ridges. It is much more applicable models results in studies of dogs, without being able to rule out the similarity of the gum of pork with humans in some aspects such as the thickness of the oral epithelium, the basal membrane and cell contents. This is why the results can be extrapolated within certain limits to humans, in addition to the obvious ethical constraints that prevent the conduct of this type of experimental study on human gums.

We consider that carrying out studies to evaluate the force needed to cut gingival tissue is very to create knowledge and advance in the utilization of robotic technology fin oral surgery, just as in some medical fields such as that studied by Chanthasopeephan10,20,21. This will allow clinics to not only perform operations in soft tissue with more precision but to take a step further into future dentistry. In the present study, even though the regular amplitude sample was not taken, the objective of comparing forces and depth in porcine gingival tissue was achieved, offering the possibility of doing parametric studies and giving greater statistical force to the obtained results.

Some limitations of this study are the collection and processing of the sample, in terms of preservation of porcine tissue to avoid their decomposition at the time of analysis. Since it was not possible to obtain such samples in a timeless to them 24 hours of sacrificed the specimen, is lose properties that are it more closely possible of them properties in vivo. Literature reports that, in experiments carried out in ex vivo tissue, tissue preparation before the experiment helps to keep its in vivo properties as

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faithfully as possible. To maintain these properties, porcine tissue to be used must be within two hours post-mortem, placed on a bed of gauze soaked with saline solution, and sealed in a container12, 22.

CONCLUSION

The gum is a tissue that' is constantly submitted to injuries by dental workers when performing any surgical procedure; therefore, it is important to know the force needed to make an incision on the tissue and the penetration depth. By the end of the study, after analyzing samples of porcine gingival tissue in the laboratory, which were previously prepared using the texture analyzer and a number 15 scalpel blade and applying vertical forces to determine cutting depth and applied force differences in the anterior and posterior sections, we found the cutting depth is greater in the posterior section (2.160 mm) than in the anterior section (1.747 mm), while when comparing the applied force in both situations there was no statistically significant difference (p>0.05).

This indicates that when using a determined amount of strength in ex vivo porcine tissue, cutting depth will be greater in the posterior section than in the anterior section, which may be caused by the anatomy of the mandibles used.

DECLARATION ON CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest of any kind.

AUTHORS' CONTRIBUTIONS

All the authors contributed to the work presented in this article. Arnulfo Tarón Dunoyer and Antonio Diaz Caballero carried out the experiments, designed the research plan, organized the study, interpreted the data and help to write the paper. Eliana Avila Martinez and Efrén Castellar Vasquez performed the statistical analysis and helped to interpret data, discuss results and write the paper.

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