UNIVERSIDADE FEDERAL DE SANTA CATARINA
CENTRO DE CIÊNCIAS DA SAÚDE
CURSO DE GRADUAÇÃO EM ODONTOLOGIA

MARCOS TESTA MAGOGA

EFEITO DO REGIME DE RADIOTERAPIA NA RESISTÊNCIA AO DESLOCAMENTO DE CIMENTOS ENDODÔNTICOS DE DIFERENTES BASES

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Trabalho de conclusão apresentado ao curso de Odontologia da Universidade Federal de Santa Catarina para obtenção do título de cirurgião-dentista.

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Marcos Testa Magoga

Efeito do regime de radioterapia na resistência ao deslocamento de cimentos endodônticos de diferentes bases

Este Trabalho de Conclusão de Curso foi julgado adequado para obtenção do título de Cirurgião Dentista e aprovado em sua forma final pelo Curso de Graduação em Odontologia.

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RESUMO

O objetivo deste estudo foi avaliar o efeito do regime de radioterapia (50 Gy e 70 Gy) na resistência ao deslocamento de cimentos endodônticos de diferentes bases. Quarenta e cinco incisivos bovinos foram decoronados e noventa discos de dentina com 1 mm de espessura dos terços cervical e médio (quarenta e cinco de cada) foram obtidos. Os discos de dentina (terços cervical e médio) foram distribuídos em três grupos, de acordo com o regime radioterápico (n=15): não irradiado; 50 Gy; e 70 Gy. Em seguida, três cavidades semelhantes a canais radiculares de 1,0 mm de diâmetro foram realizadas em cada disco de dentina. Após irrigação com solução de NaOCl à 2,5% e EDTA à 17%, cada cavidade foi preenchida com os seguintes cimentos: AH Plus Jet, BioRoot RCS e Endofill (n=15). Após 7 dias de armazenamento controlado em estufa à 37 graus celsius e 100% de umidade relativa do ar, o teste de micro *push-out* foi realizado em Máquina Universal de Ensaios. As falhas foram analisadas em estereomicroscópio. A análise estatística foi realizada com testes de ANOVA de três fatores e *post-hoc* de Bonferroni (α=5%). Os espécimes não-irradiados preenchidos com AH Plus Jet e BioRoot RCS apresentaram valores de resistência de união superiores aos irradiados, independentemente do regime de radioterapia (p<0,001). Não houve diferenças entre os espécimes irradiados com 50 Gy e 70 Gy, tanto para AH Plus Jet quanto para BioRoot RCS (p>0,05). Não houve diferenças entre amostras não-irradiadas e irradiadas para Endofill no terço cervical (p=0,406). O modo de falha coesiva foi o mais frequente antes da irradiação. Após a irradiação, o mais frequente foi o adesivo. A radioterapia foi associada à menor resistência de união micro *push-out* para os cimentos à base de resina epóxi e biocerâmico, independentemente do regime radioterapia. O cimento à base de óxido de zinco apresentou menor resistência de união.

Palavras-chave. Cimento obturador, Endodontia, Obturação, Resistência ao cisalhamento, Radioterapia.

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1. INTRODUÇÃO

As diversas formas de câncer de cabeça e pescoço CCP podem afetar áreas distintas como, a cavidade oral, envolvendo língua, glândulas salivares, orofaringe, nasofaringe, hipofaringe, laringe e glândula tireoide (GLOBOCAN 2020). No decorrer do ano de 2020, cerca de 1.500.000 novos casos foram identificados mundialmente (GLOBOCAN 2020). Conforme apontado por Vishack et al. (2015), a maioria dos casos de CCP na região oral é histologicamente diagnosticada como carcinoma de células escamosas ou carcinoma epidermóide, frequentemente em estágios avançados localmente, com uma taxa de sobrevida dos pacientes em torno de 5 anos.

A radioterapia (RT) geralmente é o tratamento de eleição nos casos de CCP (VISHACK *et al*. 2015). É comum ainda utilizar a cirurgia como modalidade de tratamento primário, tendo como adjuvante a RT e/ou a quimioterapia (SOARES *et al.* 2011). Com o aumento dos casos de CCP em todo o mundo, a RT se faz cada vez mais presente como método de tratamento (VISHACK *et al*. 2015).

A RT tem como princípio de ação a aplicação de radiação ionizante sobre os tecidos acometidos, tornando a área eletricamente instável (JHAM & DA SILVA-FREIRE 2006). O procedimento radioterápico padrão para CCP é realizado com a aplicação de doses diárias de radiação ionizante de 2 Gy, totalizando entre 50 Gy e 70 Gy ao final do tratamento, dependendo do local, extensão e estadiamento do tumor (JHAM & DA SILVA-FREIRE 2006; KIELBASSA *et al.* 2006; LIESHOUT & BOTS 2014). A duração do tratamento leva entre 5 e 7 semanas, sendo as doses aplicadas 5 dias por semana (JHAM & DA SILVA-FREIRE 2006; KIELBASSA *et al.* 2006; LIESHOUT & BOTS 2014).

No entanto, a RT não é capaz de atuar somente contra as células tumorais, podendo causar efeitos adversos aos tecidos sadios adjacentes (JHAM & DA SILVA-FREIRE 2006). Diversas alterações nas estruturas dentais são observadas quando pacientes portadores de CCP são submetidos à RT (CUNHA *et al.* 2017).

A osteorradionecrose é mais uma das graves complicações causadas pela RT, caracterizando-se por falhas na reparação óssea da região irradiada (HUANG 2019). Desta forma, diversos procedimentos odontológicos devem ser realizados previamente à RT, como exodontias e o tratamento endodôntico (LYLLI 1998; HUANG 2019).

A obturação é um dos principais passos do tratamento endodôntico (TUNCEL *et al.* 2015), pois consiste no selamento tridimensional do canal principal através da união entre dentina intrarradicular e material obturador, composto por um cimento e cones de guta-percha (SCHWARTZ 2006). Os cimentos obturadores têm como principal função unir os cones de guta-percha entre si e às paredes do canal radicular (BRANSTETTER & FRAUNHOFER 1982). Diversos tipos de cimentos obturadores estão disponíveis no mercado, como os à base de óxido de zinco e eugenol, ionômero de vidro, hidróxido de cálcio, resinosos, e mais recentemente, os biocerâmicos (ZHOU *et al*. 2013).

Diversos estudos demonstraram que a RT diminui a resistência de união entre o cimento obturador e dentina intrarradicular (SOARES *et al.* 2011; MARTINS *et al.* 2015). Isso pode ser justificado pelas alterações morfológicas, químicas e microestruturais da dentina intrarradicular irradiada, como a obliteração dos túbulos dentinários devido a degradação dos prolongamentos odontoblásticos e fragmentação das fibrilas de colágeno da matriz orgânica (GONÇALVES *et al.* 2014).

Metodologias conduzidas em laboratório para avaliar a resistência de união de materiais obturadores utilizam dentes previamente instrumentados e obturados (SCELZA et al. 2014). No entanto, esta abordagem introduz um desafio no estabelecimento de uma linha de base confiável devido à complexa anatomia interna do canal radicular (SCELZA et al. 2014). Essa complexidade é ainda maior quando se considera a existência de paredes de canais radiculares não instrumentadas (SCELZA et al. 2014). Portanto, a adesão dos cimentos obturadores a essas áreas não instrumentadas, consequentemente, pode afetar o resultado dos testes convencionais de *push-out*, conforme observado por diversos estudos (WAKABAYASHI et al. 1995; ASSMANN et al. 2011).

Tendo isso em mente, Scelza et al. (2014) desenvolveram um método laboratorial, denominado micro *push-out*, para aumentar a confiabilidade interna do modelo de teste *push-out*. Os autores criaram meticulosamente cavidades artificiais semelhantes a canais radiculares dentro do substrato dentinário para estabelecer um ponto de partida consistente e garantir uma base equitativa para comparar materiais obturadores de diferentes naturezas químicas (SCELZA et al. 2014).

Desta forma, este estudo foi desenhado para verificar se regimes distintos de radioterapia (50 e 70 Gy) afetariam a resistência de união de cimentos obturadores de diferentes bases utilizadas para preencher cavidades semelhantes a canais radiculares na, através do teste de micro *push-out*.

2. OBJETIVOS

2.1. Objetivo Geral

Avaliar o efeito de regimes de radioterapia distintos na resistência de união de cimentos obturadores de diferentes bases à dentina intrarradicular.

2.2. Objetivos específicos

- Analisar através do teste de micro *push out* a resistência de união de um cimento à base de resina epóxica à dentina intrarradicular irradiada com 50 e 70 Gy.

- Analisar através do teste de micro *push out* a resistência de união de um cimento biocerâmico à dentina intrarradicular irradiada com 50 e 70 Gy.

- Analisar através do teste de micro *push out* a resistência de união de um cimento à base de óxido de zinco e eugenol à dentina intrarradicular irradiada com 50 e 70 Gy.

2.3. Hipóteses nulas

- Os diferentes regimes de radioterapia não afetariam o desempenho dos cimentos obturadores no teste de micro *push-out*.

- Não haverá diferença na resistência de união entre os cimentos obturadores testados, independentemente do regime de radioterapia.

3. ARTIGO CIENTÍFICO

Este estudo foi preparado e escrito na forma de artigo científico de acordo com as normas para submissão no periódico *Brazilian Dental Journal* (Qualis A2, Fator de Impacto 1.845).

Effect of the radiation therapy regimen on the dislodgement resistance of endodontic sealers of different bases

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Abstract

The aim of this study was to evaluate effect of the radiation therapy regimen (50 Gy and 70 Gy) on the dislodgement resistance of endodontic sealers of different bases. Forty-five bovine incisors were decoronated and ninety 1-mm thick dentin slices from the cervical and middle thirds (forty-five of each) were obtained. The dentin slices (cervical and middle thirds) were distributed into three groups, according to the radiation therapy regimen (n=15): non-irradiated; 50 Gy; and 70 Gy. Next, three 1.0 mm diameter root canal-like cavities were made in each dentin slice. After rinsing with 2.5% NaOCl solution and 17% EDTA, each cavity was filled with the following sealers: AH Plus Jet, BioRoot RCS and Endofill (n=15). After 7 days of controlled storage in an oven at 37 Celsius degress and 100% relativity humidity, a micro push-out test was performed in a Universal Testing Machine. Failures were analyzed using a stereomicroscope. Statistical analysis was performed with Three-Way ANOVA and Bonferroni's post-hoc test ($\alpha=5\%$) tests. Non-irradiated specimens filled with AH Plus Jet and BioRoot RCS had higher bond strength values than the irradiated ones, regardless of the radiation therapy regimen ($p<0.001$). There were no differences between specimens irradiated with 50 Gy and 70 Gy, for both AH Plus Jet and BioRoot RCS ($p>0.05$). There were no differences among non-irradiated and irradiated specimens for Endofill at the cervical third ($p=0.406$). Cohesive failure mode was the most frequent before irradiation. After irradiation, the most frequent was the mixed ones. Radiation therapy was associated with lower micro push-out bond strength of epoxy resin and bioceramic sealers, regardless of the dose regimen. The zinc oxide-based sealer had the lower micro push-out bond strength.

Keywords. Dental cement, Endodontics, Obturation, Shear strength, radiation Therapy.

Introduction

Radiation therapy is a common treatment approach for individuals diagnosed with head and neck cancer (1). While surgery remains a prevalent primary treatment option, it is often complemented with adjuvant therapies, such as radiation therapy and/or chemotherapy (2). As the global incidence of HNC continues to rise, the role of radiation therapy as a treatment modality is becoming increasingly prominent (1).

The fundamental mechanism of radiation therapy involves the administration of ionizing radiation to the affected tissues, inducing electrical instability within the targeted area (3). In the conventional radiation therapy regimen for head and neck cancer, patients typically receive daily doses of 2 Gy of ionizing radiation. The total radiation dosage administered by the end of treatment ranges between 50 Gy and 70 Gy, contingent upon the tumor's location, extent, and staging (3-5). The treatment duration spans from 5 to 7 weeks, with radiation doses administered five days a week (3-5).

Nonetheless, radiation therapy does not exclusively target tumor cells and may result in adverse effects on nearby healthy tissues (3). Osteoradionecrosis is one of the most severe complications arising from radiation therapy, marked by impaired bone healing in the irradiated site (5). Consequently, several dental procedures, including extractions and endodontic treatment, should be undertaken before initiating radiation therapy (5,7).

Obturation represents a crucial stage in endodontic treatment (6). It involves achieving a three-dimensional seal within the root canal by promoting adhesion between the intraradicular dentin and the filling material, which comprises a sealer and gutta-percha cones (7). The primary role of the endodontic sealer is to create bonding among the gutta-percha cones and the root canal walls (8). A great number of endodontic sealers are available in the market, including those based on zinc oxide, glass ionomer, calcium hydroxide, epoxy resin, and, more recently, tricalcium silicate, also known as bioceramic sealers (9).

Several studies have reported that radiation therapy decreases the bond strength between the filling material and intraradicular dentin (2,10). This may be explained by the morphological, chemical, and microstructural alterations observed in the irradiated intraradicular dentin (11). These changes include the closure of dentinal tubules resulting from the degradation of odontoblastic processes and the fragmentation of collagen fibrils within the organic matrix of the dentin (11).

The methodologies conducted in laboratory settings to assess the push-out bond strength of root canal filling materials use previously prepared and obturated teeth (12). However, this approach introduces a challenge in establishing a dependable baseline due to the complex internal anatomy of the root canal (12). This complexity is further compounded when considering the existence of non-instrumented root canal walls (12). Therefore, the adhesion of endodontic sealers to these non-instrumented areas, consequently, may affect the outcome of the conventional push-out tests, as observed by several studies (13,15-17).

Bearing this in mind, Scelza *et al.* (12) developed a laboratory method, named micro push-out, to enhance the internal reliability of the push-out test model. The authors meticulously created artificial root canal-like cavities within the dentin substrate for establishing a consistent starting point and ensures a equitable basis for comparing several filling materials (12).

Therefore, this study was designed to verify whether the regimens of radiation therapy (50 Gy and 70 Gy) affected the dislodgement resistance of endodontic sealers of different chemical bases used to fill artificial root canal-like cavities, through this micro push-out test. The following null hypotheses were tested: (i) the different regimens of radiation therapy would not affect the micro push-out performance of the endodontic sealers, and (ii) there would be no difference in the intracanal bond strength among the tested sealers.

Materials and methods

Experimental design and sample size calculation

To assess the micro push-out bond strength of the endodontic sealers to the irradiated dentin, a 3 × 2 × 2 experimental design was adopted, with the sealers (three levels), radiation therapy regimen (50 Gy or 70 Gy), and root third location (cervical and middle thirds) as factors. Using the G*Power software (version 3.1.9.6; http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3/), the calculation of the sample size was conducted considering the following parameters: $\alpha=0.05$ and a statistical power of 90%. Each of the experimental groups required a total of 15 repetitions.

Specimens selection and preparation

Forty-five bovine incisors recently extracted were generously provided by a local slaughterhouse. In accordance with the institutional guidelines governing this research, ethical clearance was not deemed necessary for the present study. The teeth underwent a disinfection process involving immersion in a 0.5% chloramine solution for 48 hours, followed by a 24-hour rinse under continuous tap water flow. The removal of periodontal ligament was accomplished using scalpels and gauze pads. Subsequently, a meticulous visual examination was conducted at 4× magnification using a magnifying lens, followed by digital radiographic analysis, leading to the exclusion of teeth displaying any indications of resorptions, calcifications, cracks, or fractures from the ultimate sample set.

The bovine teeth were decoronated at the cementoenamel junction with a double-sided diamond disc (KG Sorensen, Cotia, SP, Brazil) at low-speed rotation (Model 605; Kavo, Joinville, SC, Brazil), under continuous water cooling. Specimens with an overall length of 16 mm were acquired. Subsequently, each root was individually placed in a silicone mold (25 mm x 10 mm) and immersed in transparent self-curing acrylic resin (Dencrilay; Dencril, Vaieiras, SP, Brazil) for embedding. Following curing, the roots embedded in the acrylic resin block were cross-sectioned perpendicular to their longitudinal axis using a double-sided diamond saw (Buehler, Lake Forest, IL, USA) coupled to metallographic cutter (Isomet 1000; Buehler) under continuous water cooling. Ninety dentin slices (2.0 ± 0.1 mm thick) from the cervical and middle thirds (forty-five of each) were obtained. The thickness of each dentin slice was confirmed using a digital caliper (Nagano, São Paulo, SP, Brazil).

For each dentin slice, a 1.0 mm cylindrical diamond bur (1012, KG Sorensen, São Paulo, SP, Brazil) was used to create three root canal-like cavities on the surface facing the coronal portion. The cavities were mechanically created parallel to the root canal lumen, under continuous water flow for cooling. The distance established between the root canal-like cavities, the root canal lumen and the root cementum surface was 1.0 mm (12) (Figure 1). Next, the dentin slices (cervical and middle thirds) were distributed into three groups, according to the radiation therapy regimen (n=15): non-irradiated dentin slices; dentin slices irradiated with 50 Gy; and dentin slices irradiated with 70 Gy.

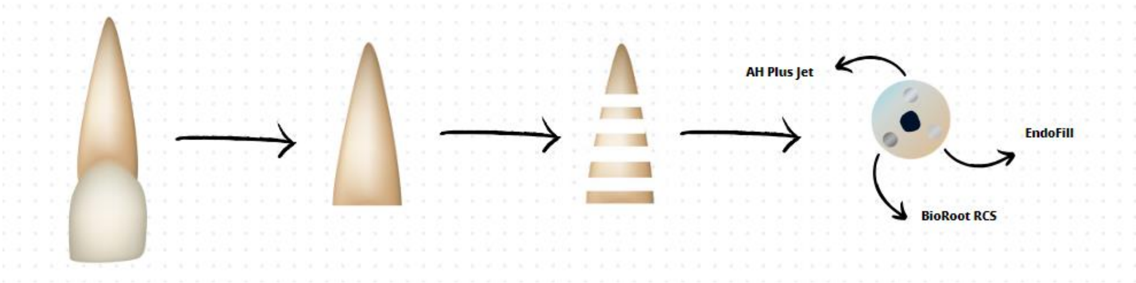

Figure 1. Root canal-like cavities in the root dentin slice.

Specimens irradiation

The irradiation of the dentin slices was conducted at the Department of Radiotherapy of the Oncology Research Center (CEPON - Florianópolis, SC, Brazil) in a linear accelerator (Clinac 2100C; Varian Medical Systems, Inc., Palo Alto, CA, USA), by the Intensity Modulated Radiotherapy Technique with dynamic collimators. The dentin slices were fully immersed in distilled and deionized water in a plastic container. The irradiation was executed in accordance with the CEPON's head and neck cancer treatment protocol, employing 6MV energy (photons) and a total dose of 50 or 70 Grays (Gy) (14,15). The irradiation doses were administered daily at 2 Gy per session, for five consecutive days a week, for five or seven weeks, depending on the radiotherapy regimen adopted for each experimental group. The distilled and deionized water was replaced at the conclusion of each daily irradiation cycle, with the specimens being immersed in artificial saliva at 37ºC to replicate the oral conditions. The initiation of a new irradiation cycle necessitated replacing the artificial saliva with distilled and deionized water. On completion of the dentin slices irradiation, the specimens were once again stored in artificial saliva at 37ºC. The whole procedure was assisted by a medical physicist and a medical radio-oncologist.

Root canal-like cavities filling

Before filling with the endodontic sealers, the dentin slices underwent a thorough rinsing with a 2.5% sodium hypochlorite solution for 30 seconds (Biodinâmica, Ibiporã, PR, Brazil), followed by 17% EDTA (Merck, Darmstadt, Germany) for 1 minute, and 2.5% sodium hypochlorite solution for 30 seconds. Subsequently, the dentin slices were carefully dried using absorbent paper.

The dentin slices from each experimental condition (radiation therapy regimen) were distributed and individually mounted onto a glass plate and fixed with wax. The three root canal-like cavities of the same dentin slice were randomly filled with one of the tested endodontic sealers: AH Plus Jet (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), BioRoot RCS (Septodont, Saint-Maur-des-fossés, France) and EndoFill (Dentsply, Rio de Janeiro, RJ, Brazil) (Table 1).

The endodontic sealers were prepared in accordance with the instructions provided by their respective manufacturers. The endodontic sealers were placed within the root canal-like cavities until a slight excess was noticeable. The prevention of bubbles formation was ensured through gentle vibration during the endodontic sealer placement process. To remove any endodontic sealer excess and create flat surfaces, a combination of a polyester strip and a glass plate was positioned on the dentin slices. A clamp was used to hold the set in place. Subsequently, the samples were placed in an oven at 37ºC and 100% relative humidity for one week to allow the sealers' setting. Following this period, the dentin slices were removed from the glass plates, and their surfaces were smoothed using 600-grit sandpaper under continuous water cooling.

Table 1. Composition of the tested endodontic sealers.

Sealer	Composition	Manufacturer	Lot number
AH Plus Jet (epoxy resin-based sealer)	Paste A: bisphenol-A epoxy resin, bisphenol-F epoxy resin, calcium tungstate, zirconium oxide, silica, iron oxide pigments. Paste B: dibenzyldiamine, aminoadamantane, tricyclodecane-diamine, silicone oil.	Dentsply Tulsa Dental Specialties, Tulsa, OK, USA	2203000461
BioRoot RCS (bioceramic sealer)	Powder: tricalcium silicate, zirconium oxide, povidone. Liquid: calcium chloride dihydrate, areo, purified water.	Septodont, Saint-Maur-des-fossés, France	B25218
Endofill (zinc oxide-based sealer)	Powder: zinc oxide, hydrogenated resin, bismuth subcarbonate, barium sulfate and sodium borate. Liquid: eugenol, almond oil and BHT.	Dentsply, Rio de Janeiro, RJ, Brazil	334423J

Micro push-out assessment

For the micro push-out test, a single dentin slice was chosen for each root third. The dentin slice was affixed onto a stainless-steel base plate that held a 2.0-mm diameter hole at its center. This stainless-steel base plate was secured to the lower section of the Universal Testing Machine (Instron model 4444, Instron Corp, Canton, USA). A cylindrical metallic plunger with a diameter of 0.8 mm was accurately placed over the endodontic sealer within each root canal-like cavity. The force was applied in the apical-coronal direction. The experiment was carried out using a crosshead speed of 0.5 mm per minute until the point of bond failure was reached. The peak load during the sealer displacement was recorded in kiloNewtons (kN), then converted into Newtons (N), and further transformed into MegaPascal (MPa). This conversion was achieved by dividing the required force (F) by the lateral area of the root canal-like cavity (LA). The area of sealer adhesion to the root dentin was determined using the equation:

$$LA = 2\pi \, r \times h$$

"π" is a constant (3.14), "r" represents the radius of the root canal-like cavity, and "h" stands for the height of the endodontic sealer (2.0 mm).

Failure mode analysis

Following the micro push-out testing, the fractured specimens were kept in plastic flasks containing saline solution for 24 hours. The specimens were then subjected to scrutiny using a stereomicroscope (SteREO Discovery.V12; Carl Zeiss, Jena, Germany) at magnifications of 40× and 100×. Failure modes were classified into four sub-types: (a) adhesive failure – at least 75% of the dentin surface free of endodontic sealer; (b) cohesive failure at sealer - endodontic sealer fracture; dentin walls still covered by sealer; (c) cohesive failure at dentin - disruption of the dentin structure, regardless of the failure mode of the endodontic sealer; and (d) mixed failure - part of the dentin walls remained covered by the endodontic sealer (Figure 2).

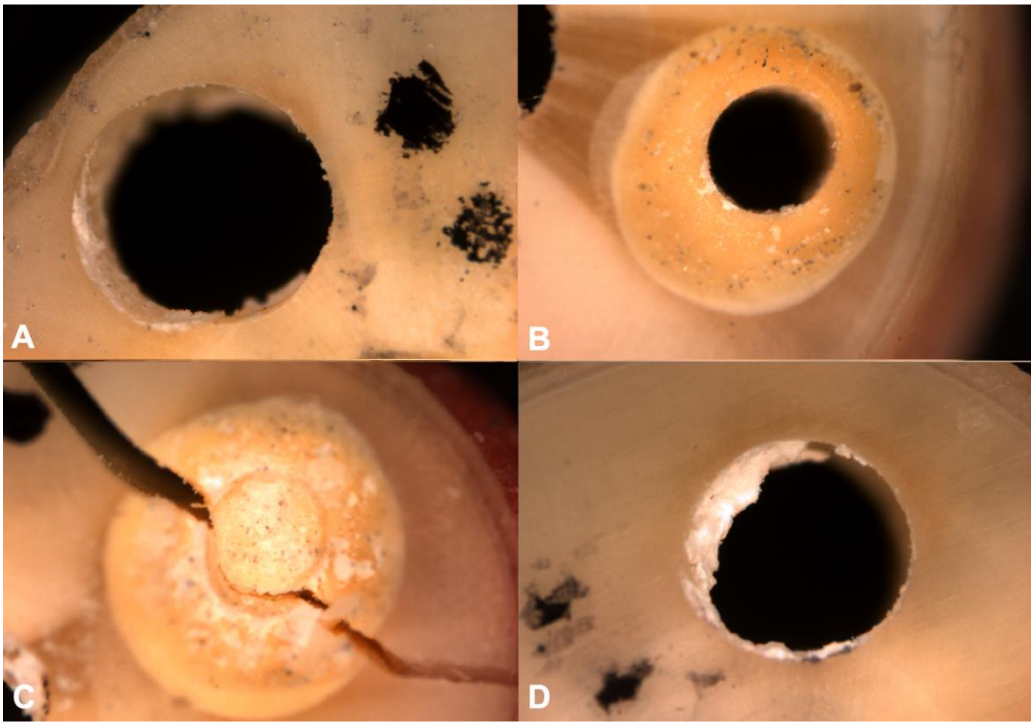

Figure 2. Representative images of the failure modes. (A) adhesive failure; (B) cohesive failure at the sealer; (C) cohesive failure at the dentin; and (D) mixed failure.

Statistical analysis

The data underwent the Shapiro-Wilk test to assess normality and the Levene test to evaluate homogeneity of variance. The statistical analysis was performed with the IBM SPSS Statistics software (IBM Corp., Armonk, NY, USA). To evaluate the effect of radiation therapy regimen, endodontic sealers and root thirds on the micro push-out bond strength values, as well as their interaction, a three-way Analysis of Variance (ANOVA) test was applied to the data. To further investigate significant differences, the analysis was complemented by Bonferroni's posthoc test. The failure mode distribution within the different experimental groups was compared by Fisher's exact test. The predetermined level of statistical significance was set at $\alpha = 0.05$.

Results

No specimen was lost during the experiment. Micro push-out bond strengths for the experimental groups in the different root thirds are shown in Tables 2 and Figure 3.

Radiation therapy

Non-irradiated specimens filled with AH Plus Jet and BioRoot RCS had higher bond strength values than the irradiated ones, regardless of the radiation therapy regimen (50 Gy and 70 Gy) ($p<0.001$). There were no differences between specimens irradiated with 50 Gy and 70 Gy, for both AH Plus Jet and BioRoot RCS ($p>0.05$).

There were no differences between non-irradiated and irradiated specimens filled with Endofill at the cervical third ($p=0.406$). In the middle third, non-irradiated specimens had higher bond strength values than specimens irradiated with 70 Gy ($p=0.028$). Specimens irradiated with 50 Gy had no difference in comparison with the other groups ($p>0.05$).

Endodontic sealers

AH Plus Jet had higher bond strength values than BioRoot RCS and Endofill in all experimental scenarios (irradiated and non-irradiated specimens), regardless of the root third ($p<0.001$). BioRoot RCS had higher bond strength than Endofill in non-irradiated specimens at cervical and middle thirds ($p<0.001$), and at the middle root third for specimens submitted to 50 Gy of radiotherapy ($p<0.001$).

Root thirds

The variance analysis revealed that the dentin location (cervical and middle root thirds) had no effect on the micro push-out bond strength values in neither of the experimental scenarios (radiation therapy regimen - 50 Gy and 70 Gy) for the AH Plus Jet and BioRoot RCS sealers ($p>0.05$). The root third had an effect on the Endofill sealer ($p<0.05$).

Table 2. Micro push-out bond strength values (Mean ± standard deviation), according to the radiation therapy regimen, endodontic sealers, and root thirds.

Radiation therapy regimen	Root thirds							
	Cervical				Middle			
	AH Plus Jet	**BioRoot RCS**	**Endofill**	p-value	**AH Plus Jet**	**BioRoot RCS**	**Endofill**	p-value
Non-irradiated	8.18 ± $0.98^{A,a}$	5.18 ± $1.27^{A,b}$	3.21 ± $0.51^{A,c}$	p<0.001	8.73 ± $1.53^{A,a}$	5.04 ± $1.42^{A,b}$	3.11 ± $0.57^{A,c}$	p<0.001
50 Gy	5.49 ± $1.76^{B,a}$	2.3 ± $1.02^{B,b}$	1.86 ± $0.67^{A,b}$	p<0.001	5.34 ± $0.9^{B,a}$	3.19 ± $0.82^{B,b}$	2.13 ± $0.63^{AB,c}$	p<0.001
70 Gy	5.17 ± $1.56^{B,a}$	3.1 ± $0.86^{B,b}$	2.39 ± $0.77^{A,b}$	p<0.001	5.15 ± $1.4^{B,a}$	2.73 ± $1.34^{B,b}$	2.04 ± $0.81^{B,b}$	p<0.001
p-value	p<0.001	p<0.001	p=0.406		p<0.001	p<0.001	p=0.028	

Different uppercase letters in a column indicates statistical difference regarding the radiotherapy regimen (Three-way ANOVA and Bonferroni tests).
Different lowercase letters in a row indicates statistical difference regarding the endodontic sealers (Three-way ANOVA and Bonferroni tests). α=0.05.

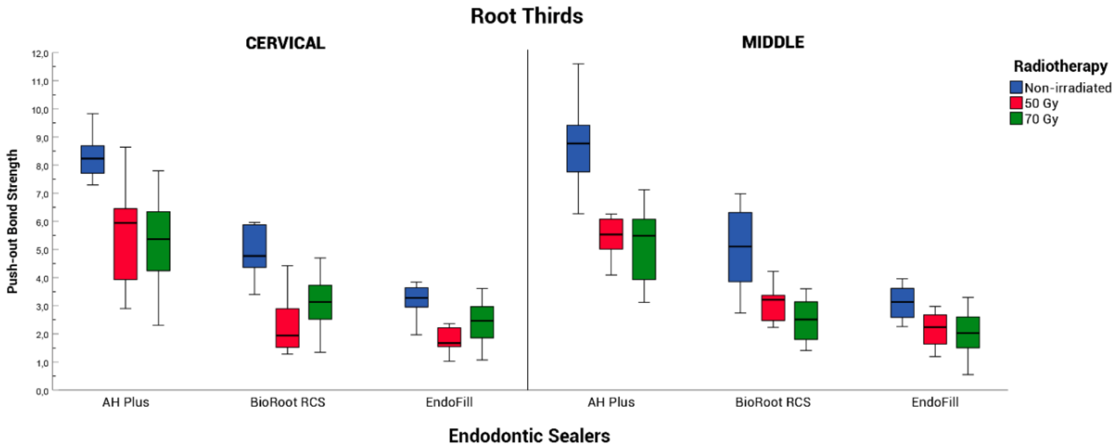

Figure 3. Boxplot of the micro push-out bond strength values according to the radiation therapy regimen, endodontic sealers, and root thirds.

Failure mode analysis

The percentages of different types of failure observed in each group are summarized in Figure 4. Regarding radiation therapy, significant differences were observed among the groups (non-irradiated, irradiated with 50 Gy, and irradiated with 70 Gy) in all comparisons ($p<0.01$), irrespective of the endodontic sealers and root thirds.

In the AH Plus Jet group, non-irradiated specimens predominantly exhibited cohesive failures at the sealer and cohesive failures at the dentin. Conversely, specimens that underwent radiotherapy, whether at 50 Gy or 70 Gy, showed a higher prevalence of cohesive failures at the sealer, adhesive failures, and mixed failures.

For the BioRoot RCS group, the majority of specimens displayed cohesive failures at the sealer. However, in specimens irradiated with 50 Gy or 70 Gy, a higher occurrence of adhesive and mixed failures was noted, as compared to non-irradiated specimens.

Within the Endofill group, non-irradiated specimens exhibited a higher frequency of cohesive failures at the sealer. In contrast, specimens subjected to 50 Gy and 70 Gy irradiation also displayed a significant incidence of adhesive and mixed failures.

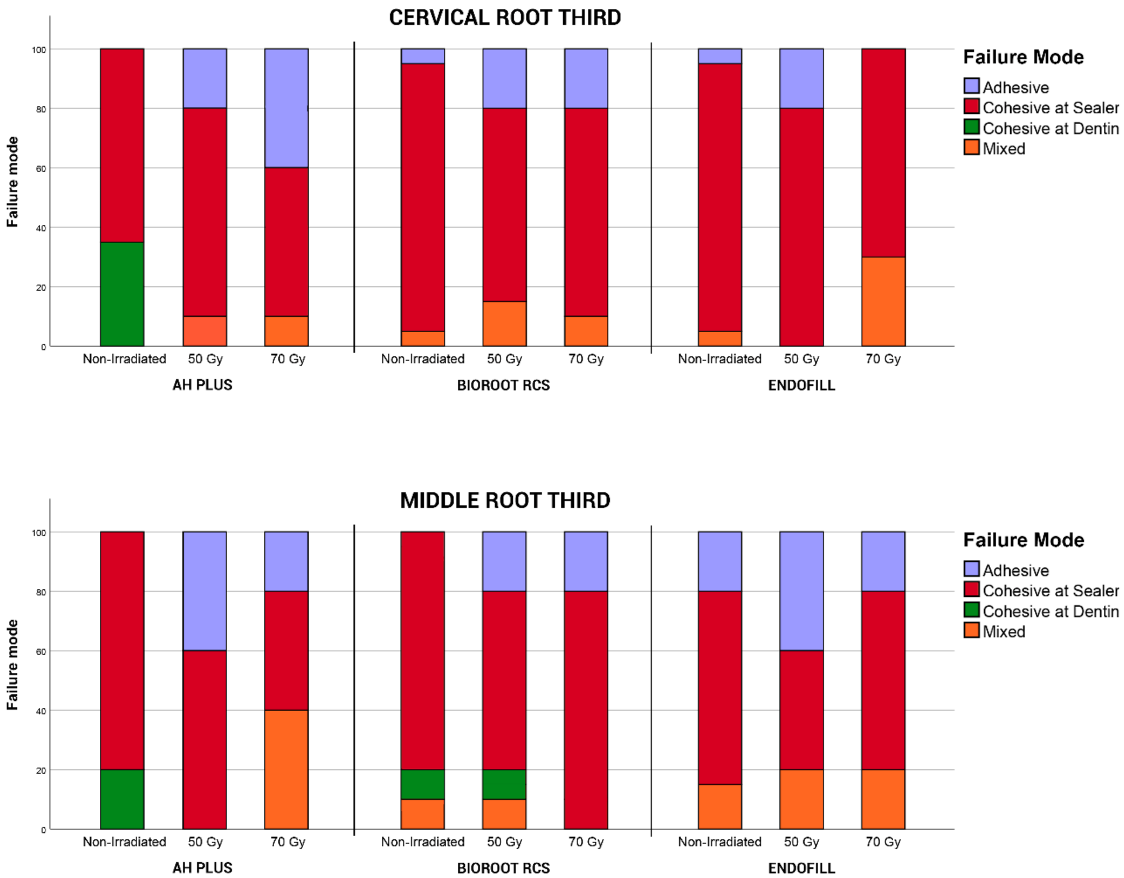

Figure 4. Graphic representation of the failure mode analysis (%).

Discussion

The bond strength of endodontic sealers is important for the long-term success of endodontic treatment, as it helps prevent microleakage and reinfection (8). Radiation-induced changes in root dentin may lead to reduced bond strength, making it challenging to achieve an effective seal in the root canal system (10,16).

Radiation therapy led to deproteinization and fragmentation of the collagen fibrils network in root dentin, however, one of the most detrimental consequences is the deterioration of the odontoblastic processes, which is subsequently accompanied by the closure of dentinal tubules (11). Therefore, it is suggested that the ability of the endodontic sealer to achieve a proper micromechanical retention of the irradiated root dentin is affected (17). While there is no conclusive evidence demonstrating whether the penetration of the endodontic sealer within the dentinal tubules directly enhances its dislodgement resistance, the scientific literature presents numerous push-out bond strength studies assessing the adhesive properties of endodontic sealers of different chemical bases (12).

According to Scelza *et al.* (12), complicating factors commonly found in the intrarradicular dentin of teeth used in the conventional push-out tests, such as the number and distribution of the dentinal tubules along the root canal length, the arrangement of the sclerotic dentin, and the dentin microhardness may enhance the micromechanical retention of the endodontic sealer within non-instrumented root canal walls. Conversely, in the present investigation, a direct comparison of different endodontic sealers was conducted using an identical source of root dentin. This approach helped mitigate potential confounding factors, such as those previously mentioned (12).

This *in vitro* study assessed the effect of the radiation therapy regimen on the dislodgement resistance of endodontic sealers of different bases through a micro push-out test method. Based on the results obtained, the first null hypothesis tested was partially rejected. The different regimens of radiation therapy affected the micro push-out bond strength of the epoxy resin (AH Plus Jet) and the bioceramic (BioRoot RCS) sealers, since non-irradiated specimens had higher bond strength than irradiated ones. However, there were no differences between specimens irradiated with 50 Gy and 70 Gy for these two endodontic sealers. Conversely, the root third location (cervical and middle thirds) played a key role in the zinc oxide-based (Endofill) sealer. Non-irradiated and irradiated specimens filled with this sealer had similar bond strength values at the cervical third. In the middle third, non-irradiated specimens had higher bond strength values than specimens irradiated with 70 Gy. The second null hypothesis was fully rejected, since the tested endodontic sealers had different bond strength performances, regardless of the experimental scenarios.

Radiation therapy protocols for head and neck cancer typically involve dose regimens spanning from 50 Gy to 70 Gy (10,14,16,20). The minimum and maximum dose regimens were administered to the specimens in a fractional manner in this study, aligning with established protocols employed in previous laboratory studies (14,16,20). Additionally, we employed the widely adopted Intensity Modulated Radiotherapy Technique, a method extensively used in clinical settings (18). This technique enables the precise delivery of high doses of radiation to cancerous cells while minimizing exposure to healthy tissues (18).

Endodontic treatment in patients undergoing radiation therapy should be aware of the potential challenge related to the sealer bond strength (10,14). Strategies to address this challenge may include using different types of endodontic sealers to ensure a reliable seal (10,14,17). For this reason, three endodontic sealers of different chemical bases were tested in this study.

AH Plus Jet had the higher micro push-out bond strength values, regardless of the radiation therapy regimen and the root third, in comparison with the other tested sealers. This epoxy resin-based sealer has shown its ability to establish chemical bonds with the collagen fibrils network within the root dentin (19,20). This interaction occurs through covalent bonds formed between the epoxy rings of the sealer and the amine groups present in dentin (19,20). However, despite the good results compared to the other sealers, the bond strength of AH Plus Jet was significantly lower in the irradiated dentin. This phenomenon may result from the interaction between ionizing radiation and dentin, which triggers the generation of free radicals, including oxygen, hydrogen and hydroxyl ions (21). These free radicals subsequently bind to other molecules and undergo reorganization, ultimately causing a change in the ionic conformation of root dentin, potentially affecting the chemical interaction with the AH Plus Jet (21).

The bond strength of BioRoot RCS was also lower in the irradiated dentin. During the setting process of bioceramic sealers, an interfacial layer characterized by tag-like structures is created due to the apatite deposition, promoting a micromechanical interlocking between the sealer and root dentin (10). However, the setting of bioceramic sealers is highly water-dependent (22). Radiation significantly impacts the water content of dentin, constituting approximately 10% of its volume (16). This radiation-induced process, named water radiolysis, results in a dehydrated dentin (16), which might affect the adhesion capacity of the bioceramic sealer.

Conversely, there were no differences between non-irradiated and irradiated specimens filled with Endofill at the cervical third, regardless of the radiation therapy regimen. Only non-irradiated specimens from the root middle third had higher bond strength than specimens irradiated with 70 Gy. Several studies have supported that bond strength in the cervical third uses to be higher in comparison with the middle and apical thirds (10,14). In the apical third, the number of dentinal tubules is lower (10,14). Also, they are smaller in diameter which limits the penetration of the sealer, playing a crucial role in the bonding capacity of the filling material to the root dentin walls (10). However, it is valid to emphasize that the bond strength values for Endofill were lower compared to other sealers in all experimental scenarios.

Regarding the failure mode, for all sealers, there was a greater incidence of cohesive-type failures in specimens that had not undergone irradiation. In contrast, following radiation therapy, a higher incidence of adhesive failures was observed, regardless of the dose regimen. It might be suggested that changes in the organic components of the root dentin occurred because of radiation therapy (16), potentially exerting an indirect influence on the bonding capacity of the endodontic sealers (10,21).

While this study sought to replicate the clinical application of endodontic sealers of different bases, it is essential to acknowledge certain constraints in this laboratory-based research. Notably, bovine teeth were used to assess the micro push-out bond strength, as opposed to the more commonly used human teeth in dental research (14,21). Obtaining a substantial quantity of human teeth in suitable conditions for experimentation may pose significant ethical challenges (23). Nevertheless, numerous studies have employed both human and bovine teeth to evaluate the adhesion of filling materials (24, 25). The consistency of results between these two models lends credibility to the use of bovine teeth in such laboratory investigations. Furthermore, to the best of our knowledge, this is the first study to subject bovine teeth to radiation therapy, and the outcomes are consistent with studies of similar purpose, affirming the feasibility of using this model for such examinations.

The effect of radiation therapy on the bond strength of endodontic sealers is a complex phenomenon and may vary among individuals. Further research is needed to better understand the specific mechanisms involved and to develop strategies to mitigate the potential negative effects of radiation therapy on endodontic treatment outcomes. In summary, radiation therapy used in the treatment of head and neck cancer may potentially affect the bond strength of endodontic sealers. Clinicians should consider these factors when treating patients who have undergone or are undergoing radiation therapy and may need to adapt their treatment approaches accordingly.

Conclusion

Within the limits of an *in vitro* study, the following conclusions may be drawn:

Radiation therapy was associated with lower micro push-out bond strength of epoxy resin and bioceramic sealers, regardless of the dose regimen. However, both sealers had the greater bond strength values. Although there was no difference between irradiated and non-irradiated specimens in the cervical third, the zinc oxide-based sealer had the lower micro push-out bond strength. Therefore, it would not be the best option for patients undergoing radiotherapy.

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Conflict of interest

The authors deny any conflicts of interest with this article.

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4. CONCLUSÕES

Apesar das limitações de um estudo *in vitro*, podem ser tiradas as seguintes conclusões:

1. A radioterapia foi associada a uma menor resistência de união micro *push-out* dos cimentos à base da resina epóxi e biocerâmico, independentemente do regime de dosagem. Entretanto, ambos os cimentos apresentaram os maiores valores de resistência de união. Embora não tenha havido diferença entre amostras irradiadas e não-irradiadas no terço cervical, o cimento à base de óxido de zinco apresentou a menor resistência de união micro push-out. Portanto, não seria a melhor opção para pacientes submetidos à radioterapia.

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ANEXO 1 – ATA DE DEFESA

UNIVERSIDADE FEDERAL DE SANTA CATARINA
CENTRO DE CIENCIAS DA SAÚDE
CURSO DE ODONTOLOGIA
DISCIPLINA DE TRABALHO DE CONCLUSÃO DE CURSO DE ODONTOLOGIA

ATA DE APRESENTAÇÃO DO TRABALHO DE CONCLUSÃO DE CURSO

Aos 27 dias do mês de OUTUBRO de 2023, às 09:00 horas, em sessão pública no (a) BLOCO F desta Universidade, na presença da Banca Examinadora presidida pelo Professor Lucas da Fonseca Roberti Garcia

e pelos examinadores:

1 - Lívia Ribeiro,

2 - Cleonice da Silveira Teixeira,

o aluno Marcos Tiski Magoga

apresentou o Trabalho de Conclusão de Curso de Graduação intitulado: EFEITO DO REGIME DE RADIOTERAPIA NA RESISTÊNCIA AO DESLOCAMENTO DE CIMENTOS ENDODÔNTICOS DE DIFERENTES BASES

como requisito curricular indispensável à aprovação na Disciplina de Defesa do TCC e a integralização do Curso de Graduação em Odontologia. A Banca Examinadora, após reunião em sessão reservada, deliberou e decidiu pela APROVADO do referido Trabalho de Conclusão do Curso, divulgando o resultado formalmente ao aluno e aos demais presentes, e eu, na qualidade de presidente da Banca, lavrei a presente ata que será assinada por mim, pelos demais componentes da Banca Examinadora e pelo aluno orientando.

Presidente da Banca Examinadora

Examinador 1

Examinador 2

Aluno

ANEXO 2 – NORMAS DA REVISTA

Geral

- Submeter o manuscrito em Word e em PDF, composto pela página de rosto, texto, tabelas, legendas das figuras e figuras (fotografias, micrografias, desenhos esquemáticos, gráficos e imagens geradas em computador, etc).
- O manuscrito deve ser digitado usando fonte Times New Roman 12, espaço entrelinhas de 1,5 e margens de 2,5 cm em todos os lados. **NÃO UTILIZAR** negrito, marcas d'água ou outros recursos para tornar o texto visualmente atrativo.
- As páginas devem ser numeradas seqüencialmente, começando no *Summary*.
- Trabalhos completos devem estar divididos sequencialmente conforme os itens abaixo:

1. Página de Rosto
2. Summary e Key Words
3. Introdução, Material e Métodos, Resultados e Discussão
4. Resumo em Português (obrigatório apenas para os autores nacionais)
5. Agradecimentos (se houver)
6. Referências
7. Tabelas
8. Legendas das figuras
9. Figuras

- Todos os títulos dos capítulos (Introdução, Material e Métodos, etc) em letras maiúsculas e sem negrito.
- Resultados e Discussão **NÃO** podem ser apresentados conjuntamente.
- Comunicações rápidas e relatos de casos devem ser divididos em itens apropriados.
- Produtos, equipamentos e materiais: na primeira citação mencionar o nome do fabricante e o local de fabricação completo (cidade, estado e país). Nas demais citações, incluir apenas o nome do fabricante.
- Todas as abreviações devem ter sua descrição por extenso, entre parênteses, na primeira vez em que são mencionadas.

Página de rosto

- A primeira página deve conter: título do trabalho, título resumido (*short title*) com no máximo 40 caracteres, nome dos autores (máximo 6), Departamento, Faculdade e/ou Universidade/Instituição a que pertencem (incluindo cidade, estado e país). **NÃO INCLUIR** titulação (DDS, MSc, PhD etc) e/ou cargos dos autores (Professor, Aluno de Pós-Graduação, etc).
- Incluir o nome e endereço **completo** do autor para correspondência **(informar e-mail, telefone e fax)**.
- A página de rosto deve ser incluída em arquivo separado do manuscrito.

Manuscrito

- A primeira página do manuscrito deve conter: título do trabalho, título resumido (*short title*) com no máximo 40 caracteres, sem o nome dos autores.

Summary

- A segunda página deve conter o *Summary* (resumo em Inglês; máximo 250 palavras), em redação contínua, descrevendo o objetivo, material e métodos, resultados e conclusões. Não dividir em tópicos e não citar referências.
- Abaixo do *Summary* deve ser incluída uma lista de Key Words (5 no máximo), em letras minúsculas, separadas por vírgulas.

Introdução

- Breve descrição dos objetivos do estudo, apresentando somente as referências pertinentes. Não deve ser feita uma extensa revisão da literatura existente. As hipóteses do trabalho devem ser claramente apresentadas.

Material e métodos

- A metodologia, bem como os materiais, técnicas e equipamentos utilizados devem ser apresentados de forma detalhada. **Indicar os testes estatísticos utilizados neste capítulo**.

Resultados

- Apresentar os resultados em uma seqüência lógica no texto, tabelas e figuras, enfatizando as informações importantes.
- Os dados das tabelas e figuras não devem ser repetidos no texto.
- Tabelas e figuras devem trazer informações distintas ou complementares entre si.
- Os dados estatísticos devem ser descritos neste capítulo.

Discussão

- Resumir os fatos encontrados sem repetir em detalhes os dados fornecidos nos Resultados.
- Comparar as observações do trabalho com as de outros estudos relevantes, indicando as implicações dos achados e suas limitações. Citar outros estudos pertinentes.
- Apresentar as conclusões no final deste capítulo. Preferencialmente, as conclusões devem ser dispostas de forma corrida, isto é, evitar citá-las em tópicos.

Resumo (em Português) - Somente para autores nacionais

O resumo em Português deve ser **IDÊNTICO** ao resumo em Inglês (Summary). OBS: **NÃO COLOCAR** título e palavras-chave em Português.

Agradecimentos

- O Apoio financeiro de agências governamentais deve ser mencionado. Agradecimentos a auxílio técnico e assistência de colaboradores podem ser feitos neste capítulo.

Referências

- As referências devem ser apresentadas de acordo com o estilo do **Brazilian Dental Journal (BDJ)**. É recomendado aos autores consultar números recentes do BDJ para se familiarizar com a forma de citação das referências.
- As referências devem ser numeradas por ordem de aparecimento no texto e citadas entre parênteses, sem espaço entre os números: (1), (3,5,8), (10-15). **NÃO USAR SOBRESCRITO**.
- Para artigos com dois autores deve-se citar os dois nomes sempre que o artigo for referido. Ex: "According to Santos **and** Silva (1)...". Para artigos com três ou mais autores, citar apenas o primeiro autor, seguido de "et al.". Ex: "Pécora et al. (2) reported that..."
- Na lista de referências, os nomes de TODOS OS AUTORES de cada artigo devem ser relacionados. Para trabalhos com 7 ou mais autores, os 6 primeiros autores devem ser listados seguido de "et al."
- A lista de referências deve ser digitada no final do manuscrito, em seqüência numérica. Citar **NO MÁXIMO** 25 referências.
- A citação de abstracts e livros, bem como de artigos publicados em revistas não indexadas deve ser evitada, a menos que seja absolutamente necessário. **Não citar referências em Português**.

- Os títulos dos periódicos devem estar abreviados de acordo com o Dental Index. O estilo e pontuação das referências devem seguir o formato indicado abaixo:

Periódico

1. Lea SC, Landini G, Walmsley AD. A novel method for the evaluation of powered toothbrush oscillation characteristics. Am J Dent 2004;17:307-309.

Livro

2. Shafer WG, Hine MK, Levy BM. A textbook of oral pathology. 4th ed. Philadelphia: WB Saunders; 1983.

Capítulo de Livro

3. Walton RE, Rotstein I. Bleaching discolored teeth: internal and external. In: Principles and Practice of Endodontics. Walton RE (Editor). 2nd ed. Philadelphia: WB Saunders; 1996. p 385-400.

Tabelas

- As tabelas com seus respectivos títulos devem ser inseridas após o texto, numeradas com algarismos arábicos; **NÃO UTILIZAR** linhas verticais, negrito e letras maiúsculas (exceto as iniciais).
- O título de cada tabela deve ser colocado na parte superior.
- Cada tabela deve conter toda a informação necessária, de modo a ser compreendida independentemente do texto.

Figuras

- **NÃO SERÃO ACEITAS FIGURAS INSERIDAS EM ARQUIVOS ORIGINADOS EM EDITORES DE TEXTO COMO O WORD E NEM FIGURAS EM POWER POINT**;
- Os arquivos digitais das imagens devem ser gerados em Photoshop, Corel ou outro software similar, com extensão TIFF e resolução mínima de 300 dpi. Apenas figuras em PRETO E BRANCO são publicadas. Salvar as figuras no CD-ROM.
- Letras e marcas de identificação devem ser claras e definidas. Áreas críticas de radiografias e fotomicrografias devem estar isoladas e/ou demarcadas.
- Partes separadas de uma mesma figura devem ser legendadas com letras maiúsculas (A, B, C, etc). Figuras simples e pranchas de figuras devem ter largura mínima de 8 cm e 16 cm, respectivamente.
- As legendas das figuras devem ser numeradas com algarismos arábicos e apresentadas em uma página separada, após a lista de referências (ou após as tabelas, quando houver).