UNIVERSIDADE UNIGRANRIO

UNIVERSIDADE MANTIDA PELA COMPANHIA
NILZA CORDEIRO HERDY DE EDUCAÇÃO E CULTURA
CNPJ 29.403.763/0001- 65

PROPEP
Pró-Reitoria de
Pós-Graduação e Pesquisa

UNIVERSIDADE DO GRANDE RIO – PROF. JOSÉ DE SOUZA HERDY

PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

IMPACT OF TRADITIONAL, CONSERVATIVE AND ULTRACONSERVATIVEACCESS CAVITY ON ROOT CANAL PREPARATION

IMPACTO DA CAVIDADE DE ACESSO TRADICIONAL, CONSERVADORA EULTRACONSERVADORA NA MODELAGEM DO CANAL RADICULAR

DISSERTAÇÃO DE MESTRADO

LUIS FELIPE JIMÉNEZ ROJAS

2023

UNIVERSIDADE DO GRANDE RIO – PROF. JOSÉ DE SOUZA HERDY
PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

IMPACT OF TRADITIONAL, CONSERVATIVE AND ULTRACONSERVATIVEACCESS CAVITY ON ROOT CANAL PREPARATION

IMPACTO DA CAVIDADE DE ACESSO TRADICIONAL, CONSERVADORA E ULTRACONSERVADORA NA MODELAGEM DO CANAL RADICULAR

LUIS FELIPE JIMÉNEZ ROJAS

Tese apresentada ao Programa de Pós-Graduação em Odontologia da Universidade do Grande Rio (UNIGRANRIO), como parte dos requisitos para a obtenção do grau de Mestre em Odontologia (Área de Concentração: Endodontia).

Orientadores:
Prof. Dr. Jose Freitas Siqueira Junior
Profa. Dra. Isabela das Neves Rôças Siqueira

2023

IMPACT OF TRADITIONAL, CONSERVATIVE AND ULTRACONSERVATIVEACCESS CAVITY ON ROOT CANAL PREPARATION

IMPACTO DA CAVIDADE DE ACESSO TRADICIONAL, CONSERVADORA EULTRACONSERVADORA NA MODELAGEM DO CANAL RADICULAR

LUIS FELIPE JIMÉNEZ ROJAS

Tese apresentada ao Programa de Pós-Graduação em Odontologia daUniversidade do Grande Rio (UNIGRANRIO), como parte dos requisitos para a obtenção do grau de Mestre em Odontologia (Área de Concentração: Endodontia).

Aprovada em 5 de Julho de 2023

Banca examinadora

Prof (a). Dr (a). Alejandro Pérez Ron
Universidade

Prof (a). Dr (a). Sabrina de Castro Brasil
Universidade

Prof (a). Dr (a). José Freitas Siqueira Jr
Universidade

Prof (a). Dr (a).
Universidade

DEDICATION

To Oralia Nahir, for being my new star in the firmament.

I love you infinitely.

ACKNOWLEDGMENTS

First of all, I thank God because he opened the doors and paths for me to carry out this Professional Master's Degree in Endodontics. Without His guidance, nothing canbe done.

To my parents, Oralia Nahir (+) and Luis Felipe, despite their fears, their support wasalways unconditional to me.

To Jean Nouel, by your side, the path has been easier.

To Alessandra Baasch and Karen Brisson, my dear companion since we studied in the Endodontics Specialty at our beloved Universidad Central de Venezuela (UCV). We have been on the path of the academy, from our beloved Venezuela, for which we want to prepare and specialize, to offer our knowledge to our students and colleagues.

To Kenny Loyo Molina, my esteemed boss and mentor, dentist and specialist in Endodontics, who has guided me and encouraged me to advance in my academic career at the (UCV).

To Professor and Doctor Flavio Alves, master's and doctoral program’s principal at the Universidade do Grande Rio (UNIGRANRIO), my new and appreciated academic institution where people welcomed me with open arms and were open to share their knowledge with me.

To professors Doctor. Isabela Rôças and Doctor. José Siqueira Jr., my master’s thesis supervisors, who have offered me their knowledge, guidance, constructive criticism and academic and human consideration. I will always be grateful, it has been an honor, infinitely thanks.

To professors Doctor Sabrina Brasil, Doctor Jose Claudio Provenzano, Doctor VictorTalarico, and Doctor Kaline Romero from the *Programa de Pós-Graduação em Odontologia* (PPGO). Thanks for your great help and support in the making of my project, I will always be grateful to you.

To my academic companions, Rita Toloza, Fátima Bueno, Pilar Araya, Giuiliana Soimu, Thais Martins, Natasha Ajuz, Thamyres Monteiro, Warley Oliveira and my buddy Victor Cortez. Thank you all.

INDEX

ABSTRACT

Conservative and ultraconservative access cavities in endodontics were developed from the concept of minimally invasive dentistry and provided an alternative to traditional endodontic cavities. These types of cavities were designed to preserve most of dentin and pulp cavity roof during access preparation, in order to increase the fracture resistance of the teeth after root canal treatment. However, it is essential to evaluate the impact of these cavity types on root canal shaping. **Goals**. To evaluate the root canal shaping after preparation of traditional, conservative and ultraconservative access cavities, using micro-computed tomography (micro-CT). **Materials and methods.** Three endodontic access cavity types (traditional, conservative, and ultra- conservative) were evaluated in extracted vital mandibular molars. Specimens were scanned in micro-CT before and after canal preparation to assess the prepared surface areas of the root canal. **Results**. Canal volume increased by 45.62%, 50.14%, and 22.42% in the conservative, traditional, and ultraconservative access cavity groups, respectively, with significant differences between ultraconservative and traditional ($p < 0.05$). The canal area was also significantly increased in the traditional compared with ultraconservative access ($p < 0.05$). Thenumber of unprepared canal areas was significantly higher with the ultraconservativeaccess cavity when compared with the other groups ($p < 0.05$). Intergroup analysis did not reveal significant differences in volume, area, and structure model index (SMI) values after conservative and ultraconservative group preparations ($P > 0.05$). **Conclusions.** Ultraconservative access cavities did not offer any advantage compared to traditional and conservative endodontic cavities in any of the parameters considered. The latter two, in turn, showed no significant differences in the parameters evaluated.

Keywords: Access cavity; micro-computed tomography; minimally invasive endodontics; root canal preparation.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS, SYMBOLS AND ACRONYMS

CAC.DW	Conservative Access Cavity with divergent walls
ConsAC	Conservative Access Cavity
DOM	Dental Operating Microscope
Ga	Gauge
ISO	International Standards Organization Microcomputed
micro-CT	tomography
NaOCl	Sodium hypochlorite
RCS	Root Canal System
SAF	Self Adjusting File
SMI	Structure Model Index
TF	Twisted File
TrussAC	Truss Access Cavity by dentin
UltraAC	Ultra-conservative Access Cavity
WL	Working Length

1. INTRODUCTION AND REVIEW OF THE LITERATURE

Root fractures are a reason of concern after endodontic treatment. Modern dentistry has seen a trend towards minimally invasive treatments. Regarding endodontics, the removal of tooth structure increases the tooth susceptibility to fracture. As a result, the concept of conservative cavities has arisen (MOORE et al. 2016).

It is important to categorize the existing trends regarding a tooth´s shape to carry out the pulp access used in different endodontic procedures. SILVA et al. (2020 B) describes 6 main categories in order to provide a common language and self-explanatory abbreviations: traditional access cavity, conservative access cavity, ultra-conservative access cavity, dentin-supported access cavity, access cavity conditioned by decay and access cavity conditioned by the restoration.

Conservative access cavities in endodontics have been developed from the concept of minimally invasive dentistry. They provide an alternative to traditional endodontic cavities (CLARK & KHADEMI 2010, ALOVISI et al. 2018). This concept was based on the assumption that dentin preservation during access cavity preparation was an essential action to maintain optimal strength, fracture resistance and many other necessary characteristics for long-term function and survival of teeth with root canal filling (CLARK & KHADEMI 2010). They have been designed in an effort to preserve the tooth mechanical stability. Conservative cavities are used to preserve a greater amount of dentin, which can influence geometric shaping parameters (ALOVISI et al. 2018).

The assumption behind this concept takes into account that preserving the greatest amount possible of the pulp chamber roof during the access preparation would maintain the teeth fracture resistance after root canal treatment. However, although it continues to be clinically adopted by some dentists, the influence of minimally invasive access cavity preparation on the fracture resistance of teeth has only had limited supporting evidence (SILVA et al. 2020 B).

1.1 INFLUENCE OF ULTRA-CONSERVATIVE ACCESSES IN ENDODONTIC TREATMENTS

During root canal treatment or retreatment, the smaller the access cavity is, the more difficult it can be to visualize and debride the pulp chamber, as well as to locate, shape, clean and fill the canals. At the same time, a small access cavity may increase the risk of iatrogenic complications as a result of poor visibility, which may impact the treatment outcome (SILVA et al. 2020 B).

1.1.1 Root canal orifice location

One of the greatest inherent difficulties while performing minimally invasive access cavities, is the location of root canals entrance, which may be affected by the pulp chamber floor limited vision (SILVA et al. 2020 B). ROVER et al. (2017) indicate that **conservative access cavity (ConsAC)** in maxillary molars resulted in a minor detection of root canals when there was not used selective abrasion with ultrasound.

In one hand, the detection of additional canals when performing traditional and conservative accesses was not affected when they were associated with magnification/illumination and the use of small ultrasonic tips (ROVER et al. 2017). On the other hand, the detection of additional canals in teeth with ultraconservative access cavity was affected (SAYGILI et al. 2018). However, further studies are required to assess if the operator's knowledge, regarding the presence of additional canals, would affect their detection rate in different teeth groups with different access designs (SILVA et al. 2020 B).

1.1.2 Chemical and mechanical preparation of the root canal

When properly performed, the chemomechanical preparation allows the intracanal irrigant and medication to reach the entire length of the root canal. Traditional access cavity may lead to better preservation of the original root canal anatomy, when is compared to conservative access cavity, particularly in the apical third (ALOVISI et al. 2018) however, the **conservative access cavity (ConsAC)** improved fracture resistance more than the **traditional access cavity (TradAC)**. It could increase the risks of an inefficient canal instrumentation and procedural errors in first mandibular molars (KRISHAN et al. 2014). The instrumentation efficiency in the maxillary molars with **ConsAC** and **TradAC** was generally poor and there were not detected significant differences. Even so, it has been shown that **ConsAC** in upper molars does not seem to affect the instrumentation efficacy (MOORE et al 2016).

A study indicated that in lower anterior teeth with oval canals, there are no significant difference regarding the untouched areas in the canal with TradAC versus ConsAC (VIEIRA et al. 2020).

Remnants of infected pulp tissue may be a source for persistent infection and cause post-treatment disease (SIQUEIRA & RÔÇAS 2008). VIEIRA et al. (2020) concluded that disinfection is completely compromised after preparation in teeth with conservative access cavities.

It has been claimed that irrigant activation may improve the effectiveness of root canal debridement and disinfection in teeth with ultra-conservative access cavities. It is known that the irrigation of minimally enlarged canals may present additional disadvantages, such as limited irrigant penetration, needle wedging, the effect of vapor lock and challenges related to the irrigation with sonic/ultrasonic/apical negative pressure (BÓVEDA & KISHEN 2015).

The literature review suggests that there is no difference between traditional access cavity and conservative access cavity regarding to intact canal walls and the accumulation of hard tissue remains after preparation, while an increased canal transport was observed in teeth with conservative access cavity (ROVER et al. 2017, ALOVISI et al. 2018). In addition, smaller access cavities, such as **ultraconservative access cavity (UltraAC)** and **truss access cavity by dentin (TrussAC)**, were associated with negative effects on irrigation efficiency, because large amounts of remaining pulp tissue and hard tissue remants were left after mechanical preparation procedures. On the other hand, the influence of the access cavity design on the reduction of bacteria is still unclear andfurther studies are required (SILVA et al. 2020 B).

Only two studies have evaluated the influence of different access cavity designs and the amount of accumulated debris (ROVER et al. 2017, SILVA et al. 2020 B). No differences were observed when comparing **ConsAC** or **TrasAC** in maxillary molars, with 10 study samples (ROVER et al. 2017). Unlike SILVA et al. (2020 B) reported that in maxillary premolar with **UltraAC** is associated a greater accumulation of debris in root canal system compared to **TradAC**, evaluating 52 specimens. Both studies were evaluated by **microcomputed tomography (micro-CT).**

In other ways, VIEIRA et al. (2020) evidenced, through an ex vivo study with a sample of 62 specimens, the existent relationship between the presence of microorganisms and the relationship with the access cavity, evaluated by polymerase chain reaction studies, indicating that the number of positive cultures was significantly higher in **ConsAC** (86%) compared to **TradAC** (50%). However, the **micro-CT** evaluation indicated that there is no significant difference between prepared and unprepared walls within both study groups. As a conclusion, it is stated that the disinfection would be significantly compromised after root canal preparation in teeth with **ConsAC.**

1.1.3 Root canal filling and retreatment

A study by radiographic analysis evaluated the filling quality of unique oval-shaped root canals in mandibular premolars after traditional or conservative access cavity. The small dimensions of the conservative access cavity **ConsAC** made difficult the gutta-percha cone adaptation when a single-cone technique was used and they also hampered the implementation of the continuous wave compaction method. Consequently, it was concluded that thermosoftening lateral compaction technique would be the best option to fill root canals in teeth with conservative access preparations. Regarding the removal of root canal filling during retreatment, according to the limitations of the ex vivo study, any treatment protocol could completely remove the filling material, but when **ConsAC** design teeth are compared to **TradAC** design teeth, there is more remaining filling material on the root canal surface on the first ones (NIEMI et al. 2016).

There was not a real benefit associated to ultraconservative endodontic cavities compared to traditional cavities. The **UltraAC** resulted in more hard tissue debris remaining inside the root canals. **UltraAC** did not influence the quality of the root filling; however, the **UltraAC** made the pulp chamber cleaning procedure more difficult, increasing the total time needed to perform the root canal treatment.Besides, the **UltraAC** was not associated to an increase in fracture resistance of maxillary premolars. (SILVA et al. 2020 A).

The outcome of canal filling and retreatment procedures when different types of access preparations are used remains a topic to be explored (NIEMI et al. 2016, SILVA et al. 2020 A). So far, studies have suggested a possible influence of the cross-sectional canal shape on the outcome of filling procedures and the difficulties to remove the filling material from the pulp chamber in teeth with ultraconservative access cavities (**UltraAC)** (SILVA et al. 2020 A). Retreatment procedures with **ConsAC** took longer, while instruments with asymmetric cutting movements appeared to be more effective than other rotary instruments to remove filling materials from oval-shaped canals of single-rooted teeth with **TradAC** (SILVA et al. 2020 B).

1.1.4 **Ultraconservative access preparation on the resistance to dental fracture influence**

It is important to point out that the factors that compromise the biomechanical behavior of a tooth versus functional forces would increase its propensity to fracture. One of the most important conditions that contributes to a tooth's susceptibility to fracture includes the removal of large amounts of healthy dentin during endodontic and restorative procedures (KISHEN 2015). PLOTINO et al. (2017) demonstrate that endodontically treated teeth, regardless of the type of the access cavity performed (traditional, conservative and ultra-conservative), are more susceptible to suffer non-restorable fractures (with apical limit at the simulated bone crest level) compared to teeth without endodontic treatment.

In the literature, fourteen studies have evaluated fracture resistance of extracted teeth with minimally invasive access preparations. In five of these studies (KRISHAN et al. 2014, PLOTINO et al. 2017, MAKATI et al. 2018, ABOU-ELNAGA et al. 2019, SABERI et al. 2020), the fracture resistance of teeth with conservative and ultra-conservative access preparations were higher than traditional accesses. PLOTINO et al. (2017) determined that there is no difference in fracture resistance in conservative versus ultra-conservative access cavities. On the other hand, there were not observed differences in the other eight studies (MOORE et al. 2016, ROVER et al. 2017, CORSENTINO et al. 2018, ÖZYÜREK et al. 2018, SABETI et al. 2018, ROPERTO et al. 2019, SILVA et al. 2020 A, SILVA et al. 2021).

A systematic review of in vitro studies concluded that there is no evidence to support that the use of conservative endodontic cavities over traditional endodontic cavities increases fracture resistance in human teeth. This information is relevant because conservative access cavities have gained attention in endodontics, because they preserve the greatest amount of pericervical dentin structure, which could improve the fracture resistance of endodontically treated teeth. However, the influence of access cavity design upon fracture resistance remains limited and controversial (SILVA et al. 2018).

Micro-computed tomography technology (micro-CT) is a non- destructive method that has been used to compare root canal morphology before and after preparation in extracted teeth (SIQUEIRA et al. 2018, OLEJNICZAK & GRINE 2006). Samples remain available for further biological and/or mechanical testing (SWAIN & XUE 2009). An important parameter evaluated in micro-CTstudies, is the amount of unprepared canal surface area. Studies have revealed that approximately 10% to 50% of the main surface of the root canal remains intact by instruments (PAQUÉ et al. 2011 B, MARKVART et al. 2012, SIQUEIRA et al. 2013, PETERS et al. 2015).

Areas of the canal walls that remain unprepared after mechanized instrumentation used with 2.5% NaOCl irrigation, as revealed in an *in vitro* study by micro-CT analysis, were generally covered with debris, including pulp tissue remains, bacteria, and dentin chips, especially in the apical root canal (SIQUEIRA et al. 2018). The organic tissue and residual bacteria remaining on the untreated root canal walls can compromise the outcome of endodontic treatment. That is why there is a need to develop strategies to improve disinfection during or after oval and irregular root canal chemomechanical preparation (VIEIRA et al. 2020).

1.1.5 **Unprepared surface areas of root canal evaluated by micro-computed tomography (micro-CT)**

The chemomechanical preparation assumes a fundamental role in the treatment, because it acts mechanically and chemically on the bacterial communities that colonize the main canal (SIQUEIRA et al. 2013). It has been shown that there are areas of the main root canal that remain unprepared after instrumentation (PETERS et al. 2001). SILVA et al. (2020 A) report that the percentage of the unprepared areas after mechanical preparation in teeth with **TradAC** and **UltraAC**, evaluated with micro-CT, do not differ significantly. Similarly, VIEIRA et al. (2020) indicated that there is no significant difference in the unprepared walls between **TradAC** with **ConsAC** groups.

Two mechanical canal preparation systems (XP-endo Shaper and Reciproc Blue) have been compared with a **TradAC** access, and it was determined, by micro-CT evaluation, that more than a half of the root canal walls (56%) were not prepared by the instrumentation, because they presented residual bacteria and/or pulp tissue remains on their walls (PÉREZ et al. 2020).

The remained unprepared areas by Reciproc instruments, using a 2.5% sodium hypochlorite irrigation, under micro-CT analysis, revealed surfaces covered with debris, such as pulp tissue remnants, bacteria, and dentin debris, especially in the apical root canal. In mesial canals in mandibular molars, the unprepared area was about 18.1% and 9.6% over the complete canal length and apical portion, respectively. In mandibular premolars, the unprepared area corresponded to 34.6% in the total canal length and 17.6% in the apical portion (SIQUEIRA et al. 2018).

A study reported that non-instrumented canal areas percentage does not differ significantly between **ConsAC** (25.8%) and **TradAC** (27.4%), prepared with Reciproc instruments, studying 30 maxillary first molars (ROVER et al. 2017).

It has been demonstrated by an ex vivo study in mesial mandibular roots, prepared with three instrumentation systems (Self Adjusting File-SAF, Reciproc and Twisted File-TF), that all groups showed unprepared areas, especially in the isthmus and in the canal apical third, in a range of 25-30% (excluding the isthmus area). None of the instrumentation systems could prepare all the surface areas of the root canal (SIQUEIRA et al.2013).

An ex vivo study in oval canals, evaluated by micro-CT and using canal preparation with four different systems (SAF, WaveOne, Reciproc, and Protaper Universal), demonstrated that they had a similar performance regarding prepared dentin walls (VERSIANI et al. 2013).

Another ex vivo micro-CT study in maxillary molars determined a range between 25-30% of untreated surface with **TradAC** access under a single mechanical preparation system with Endo-Eze AET files, activated with oscillating motion (PAQUÉ et al. 2005).

It was determined that after preparation, root canal geometry changes were determined by the root canal type, rather than the technique or instruments used to prepare the canals. This conclusion was based on an ex vivo study evaluated with micro-CT in maxillary molars, using manual instrumentation, (K-files) and rotary (Lightspeed and ProFile) (PETERS et al. 2001).

A large area of the main walls of the root canal remains intact after preparation, regardless of the instrumentation technique, instrument or type of coronal access used (PETERS et al. 2001, PAQUÉ et al. 2005, SIQUEIRA etal. 2013, VERSANI et al. 2013, ROVER et al. 2017, SIQUEIRA et al. 2018, SILVA et al. 2020 A, VIEIRA et al. 2020, PÉREZ et al. 2020). Consequently, bacterial biofilms attached to the walls may not be affected in these regions (SIQUEIRA et al.2013).

The purpose of this ex vivo study is to evaluate the effects of the different traditional, conservative, and ultraconservative endodontic accesses on root canal shaping, as evaluated by micro-CT imaging.

2. HYPOTHESIS

Null hypothesis (H_0): The different endodontic access designs will not influence the shaping of root canals.

Alternative hypothesis (H_1): Conservative or ultraconservative endodontic access designs will negatively influence the shaping of root canals.

3. JUSTIFICATION

The effects of minimally invasive access preparations on root canal preparation are controversial and require more studies to clarify the issue. This ex vivo study evaluated the influence of traditional, conservative and ultra-conservative endodontic accesses on the prepared surfaces and other shaping parameters after root canal preparation with a contemporary instrument system. This investigation comprises the first study that compares the action of 3 different types of coronal accesses in the shaping of root canals from mandibular molars.

4. OBJECTIVES

To evaluate the root canal shaping during preparation of teeth in which different access designs were performed, including traditional, conservative and ultra-conservative endodontic accesses, by using micro-CT evaluation.

5. MATERIALS AND METHODS

5.1 **Sample selection and preparation**

The study protocol was submitted to The Bioethics Committee of the School of Dentistry of the Central University of Venezuela (UCV). Forty-eight freshly extracted human mandibular molars with vital pulps were selected for reasons not related to this study. Immediately after extraction, the external surfaces of these teeth were decontaminated with 2.5%NaOCl and were placed in isotonic sodium chloride solution (0.9%) and then, they were frozen and stored until the time of use. Pulp vitality was confirmed by the presence of a bulk of soft tissue in the pulp chamber, after access preparation (Fig. 1).

Fig. 1 Sample selection and preparation.

Initially, periapical radiographs were taken in the buccolingual and mesiodistal directions, using digital radiography system RVG First (Trophy Imaging). Each tooth was inspected under a Dental Operating Microscope (DOM OPTO, Brasil) at 5X magnification, to verify that the apices were completely formed and that the root and coronal surfaces were free of internal and/or external fractures, fissures, or resorptions. Ultrasonic cleaning of the roots was performed in all teeth to remove any remaining tissue.

Later, micro-computed tomography scans of the selected teeth were performed. Teeth were matched in trios, depending on micro- CT data regarding anatomical similarities preoperative canal volume and surface area, and tooth length. A sample from each trio was randomly assigned to each of the 3 experimental groups (n=16).

5.2 **Study groups**

Group 1: Sixteen (16) teeth, mesial roots, traditional access and canal preparation with RACE® R MOTION instruments.

Group 2: Sixteen (16) teeth, mesial roots, conservative access and canal preparation with RACE® R MOTION instruments.

Group 3: Sixteen (16) teeth, mesial roots, ultraconservative access and canal preparation withRACE® R MOTION instruments.

The distal roots served as the non-instrumented control group.

Size 10 and 15 K-files were used to explore the root canal until the tip of the instrument in the apical foramen was visible under an optical microscope. This measurement was recorded as both the patency length and the working length (WL) which was established at that distance (exit foramen - zero limit). Each apical foramen was sealed with TopDam sealer (FGM, Spain) to create a closed system. The root was wrapped in moistened gauze for handling. A single dental operator performed all the root canal access, negotiation and preparation procedures.

5.3 Cavity Accesses

5.3.1 - Group 1. Traditional Access Cavity (TradAC): in posterior teeth, there is a complete removal of the pulp chamber roof, to achieve straight line access to the root canal orifices, with slight divergence of the axial walls, so all orifices can be observed at the same time (VERTUCCI & HADDIX 2011) (Fig. 2).

For the access cavity procedure, #2 and #4 round burs at high speed were used, until reaching the pulp chamber, then the Endo-Z bur was used to model the final shape.

Fig. 2. Traditional Access Cavity TradAC.

5.3.2. **Group 2: Conservative Access Cavity (ConsAC):** In posterior teeth, the preparation started in the central fossa of the occlusal surface. It extended with slight convergence of the axial walls towards the occlusal surface, only as far as it is necessary to detect the root canal orifices, preserving part of the pulp chamber roof (CLARK & KHADEMI 2010). This type of access has divergent walls (CAC.PD) (ROPERTO et al. 2019) (Fig.3).

Fig. 3. Conservative Access Cavity (ConsAC).

5.3.3 - Group 3. **Ultraconservative Access Cavity (UltraAC):** known as ninja access cavities. Preparation started as described in the ConsAC, but without any kind of extension, keeping as much as possible of the pulp chamber roof and of the pericervical dentin (PLOTINO et al. 2017). The "ninja" access is derived from the oblique projection towards the central fossa of the root canal orifices in the occlusal plane. By doing this, localization of all root canal orifices from different visual angles is possible, because the endodontic access is performed at 90° with the occlusal surface (CLARK & KHADEMI 2010, PLOTINO et al. 2017) (Fig 4).

.

Fig. 4. Ultraconservative Access Cavity (UltraAC).

Micro-CT images were used to plan the preparation of the conservative and ultra-conservative access cavities. The pre-established measurements were transferred to the occlusal face (conservative access cavity and ultra-conservative access cavity) of the sample teeth with the help of a fine point indelible ink marker. This indicated the exact place to perform the access cavity. The access was made under magnification with a dental operating microscope (DOM) in all groups, using #2 and #4 round burs at high speed. The RACE® R MOTION instrument was measured using a digital caliper at the shaft area level, so the access was not less than this diameter (CONSERTINO et al. 2018).

5.4 **Root canal preparation**

All canals were initially irrigated with 2 ml of 2.5% sodium hypochlorite (NaOCl). Canal preparation was performed with RACE® R MOTION instruments (FKG Dentaire Swiss Endo, La Chaux-de-Fonds, Switzerland) with a VDW Silver engine (VDW, Munich, Germany) operated in a reciprocating motion using preset settings.

Protocol

1. An ISO 10 manual file was used to explore the canal.
2. The working length was determined. Apical permeability was verified with an ISO 15 manual file, which was introduced into the root canal until the instrument tip was visible at the apical foramen. The working length was established at this point (zero limit).
3. The apical foramen was sealed with a gingival barrier material.

4. RACE® R MOTION instruments were used in the preestablished sequence order.

5. RACE® R MOTION instruments were used by making slight back-and-forth movements of 2-3 mm and applying a very light apical pressure, to allow the instrument to advance passively along the canal. After 3 back-and-forth movements, the instrument was removed and cleaned the instrument; then the canal was irrigated and an ISO 10 manual file was used to confirm patency.

6. The R-MOTION GLIDER instrument (15/.03) was used to establish patency until achieve the working length.

7. The R-MOTION (25 /.06) instrument was used up to the working length. If necessary, a brushing motion was applied to suppress coronary interference and/or to smooth out the irregular canal shape.

8. Patency was checked again with an ISO 15 manual instrument (Fig. 5).

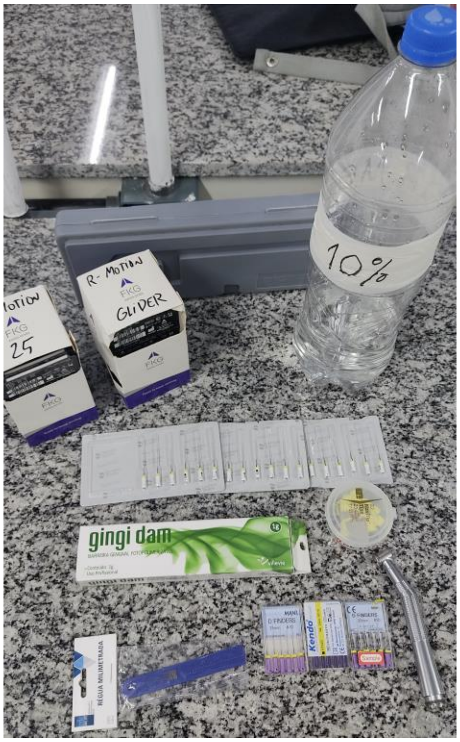

Fig. 5. Working materials and instruments

Apical patency was checked and constant irrigation of 3 ml of 2.5% NaOCl was conducted between each instrument, until the end of preparation. A 30 gauge (Ga) needle was used for irrigation (NaviTip, ULTRADENT,Utah, United States) 3 mm short of the working length. The same instrumentation procedures, including irrigation time and volume, were performed for all three groups. Each instrument was used to prepare 4 canals (2 roots).

Teeth were scanned in micro-CT once again to evaluate the prepared and unprepared areas of the root canal system for statistical analysis (Fig.6).

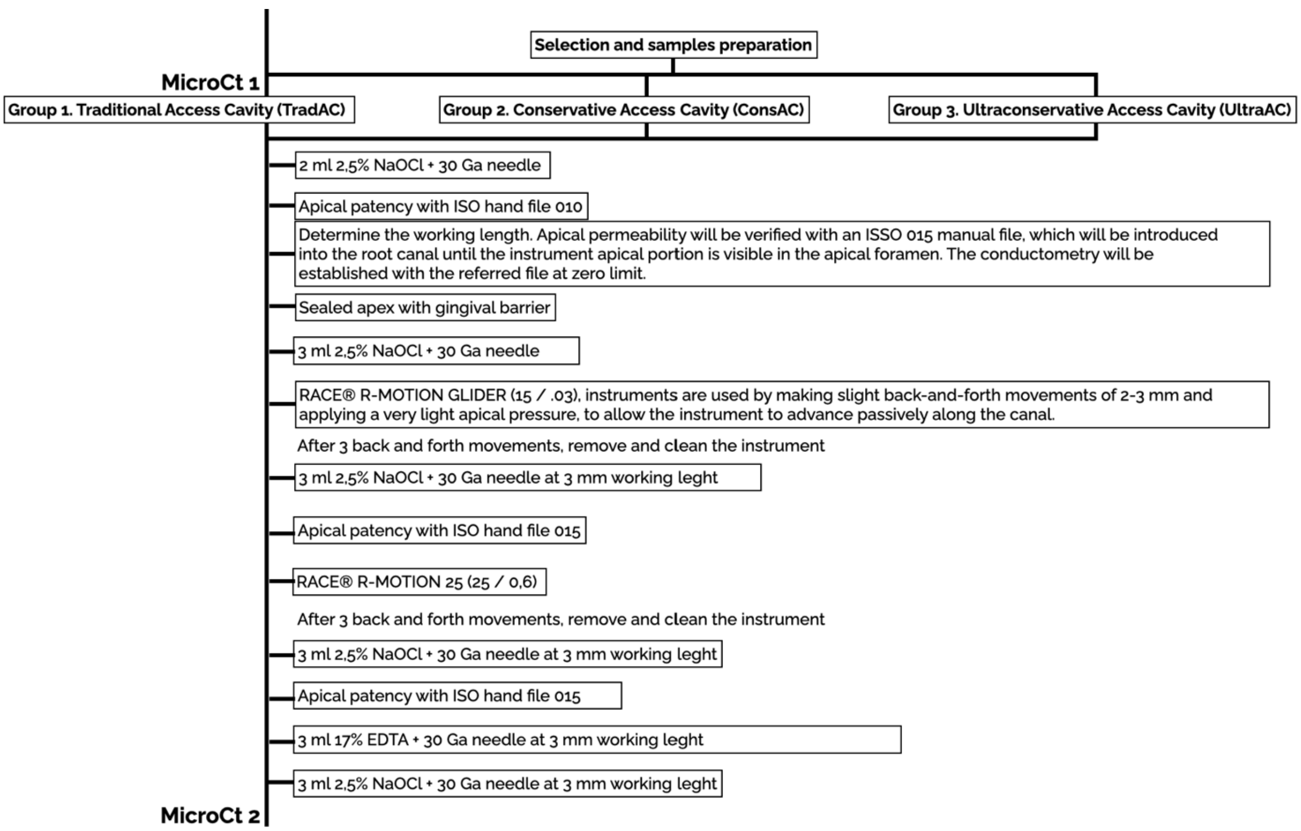

Fig.6. Work flowchart

5.5 **MicroCT analysis**

Specimens mounted on a custom platform were scanned in a micro-CT scanning device (SkyScan 1174.v2; Bruker-microCT Kontich, Belgium), before and after chemomechanical preparation. The following parameters were used: 50 kV. 800 mA, 17 mm isotropic resolution, 180 around the vertical axis, and a rotation step of 1.0 using a 0.5 mm thick aluminum filter. The images of each sample were reconstructed (NRecon v.1.6.9.16, Bruker-microCT), using smoothing 6 and beam hardening 50% as parameters (PÉREZ et al. 2020).

The CTAn v.1.14.4 (Bruker-microCT) software was used to create the three-dimensional (3D) models, the .bmp images generated with this software were converted to .nrrd in the ImageJ 1.50d software (National Institutes of Health, Bethesda, MD) before registration. The 3D Slicer 4.4.0 software from (http://www.slicer.org) was used to 3D models co-registration from pre-preparation and post-preparation images with a custom combination of a rigid registration module based on similarities with an accuracy larger than 1 voxel (PÉREZ et al. 2020).

The micro-CT scans were used to assess the root canal anatomy for sample selection, standardize the distribution between groups by matching teeth byvolume and anatomical similarities, plan access cavity preparation, and analyze the prepared canal surface areas (VIEIRA et al. 2020).

The surface area (in mm^2) and the volume (in mm^3) of the canal apical third (from the working length to 4 mm short) and the total length of the canal (from the working length to 10 mm short) were calculated using ImageJ 1.50d software. The same software was used to assess the unprepared canal surface area by calculating the static voxels numbers. They were expressed as a percentage of the total voxel numbers on the canal surface (PÉREZ et al. 2020). In order to allow a comparison of superimposed root canal models from preoperative and postoperative scans, the CTVol v.2.3.1 (Bruker-microCT) software was used to define a color-coded standard for root canal models as follows: the green color was used for the canal superficial preoperative models and the red color will be used for the postoperative surfaces (LACERDA et al. 2017, PÉREZ et al. 2020). Fig. 7.

Fig. 7. Bruker-microCT

5.6 **Statistical analysis**

The Shapiro-Wilk test was applied to verify the data normality. The Kruskal-Wallis test was used to compare groups regarding the canal area and the volume increase, the amount of unprepared areas and the Structure Model Index (SMI) before and after preparation. For intragroup analyses, Mann-Whitney U and t-tests were used to verify differences within canal volume, area and SMI before and after preparation. The significance level was set at 5% for all statistical tests ($P<0.05$).

6. RESULTS

Intergroup analysis

There were not significant differences between groups regarding the initial volume, area, and SMI ($P < 0.05$). The percentage increment rate of canal volume with root canal preparation was 45.62% (median, 36.16) for the conservative group, 50.14% (median, 55.92) for the traditional group, and 22.42% (median, 24.58) for the ultra-conservative group. There were significant differences between the ultra-conservative and the traditional groups ($P < 0.05$).

The percentage increment rate in the canal area with root canal preparation was 27.05% (median, 11.08) for the conservative group, 30.68% (median, 23.02) for the traditional group, and 3.83% (median, 3.46) for the ultra-conservative. There were significant differences between the ultra-conservative and traditional groups ($P < 0.05$).

The amount of unprepared surface area of the root canal was 17.32% (median, 16.60) for the conservative group, 13.55% (median, 12.94) for the traditional group, and 31.40% (median, 31.27) for the ultra-conservative, with significant differences between the ultra-conservative group and the others ($P < 0.05$) (Table 1) (Figs. 8, 9 and 10).

TABLE 1. Mesial root canal in mandibular molars volume and surface area before and after preparation

Access Cavity	Level	Volume (mm³)	Mean ± SD	Median	Range	Surface area (mm²)	Mean ± SD	Median	Range
TRADITIONAL	Full canal	Initial	3.08	1	1.04 – 5.39	Initial	42.255	34	21.89 – 69.31
		Final	6.112	5	2.43 – 11.3	Final	54.593	65	27.29 – 96.13
		Δ Volume%	50.14%	55.92	10.57 – 79.28	Δ Área%	30.68	23.02	3.35 – 76.18
						% unprepared	13.55 %	12.94	2.59 – 28.94
CONSERVATIVE	Full canal	Initial	3.719	1.29	0.36 – 7.9	Initial	48.698	35	20.99 – 88.22
		Final	6.44	4.48	3.51 – 12.36	Final	56.949	41	37.24 – 95.04
		Δ Volume%	45.62%	36.16	7.61 – 89.74	Δ Área%	27.05	11.08	1.31 – 99.11
						% unprepared	17.32 %	16.60	4.49 – 34.46
ULTRACONSERVATIVE	Full canal	Initial	4.647	5.5	1.59 – 10.92	Initial	50.917	64.68	24.86 – 88.91
		Final	6.247	6.47	2.05 – 14.06	Final	54.01	65.29	26.26 – 96.51
		Δ Volume%	22.42%	24.58	6.98 – 52.50	Δ Área%	3.83	3.46	0.38 – 21.85
						% unprepared	31.40 %	31.27	18.33 – 40.84

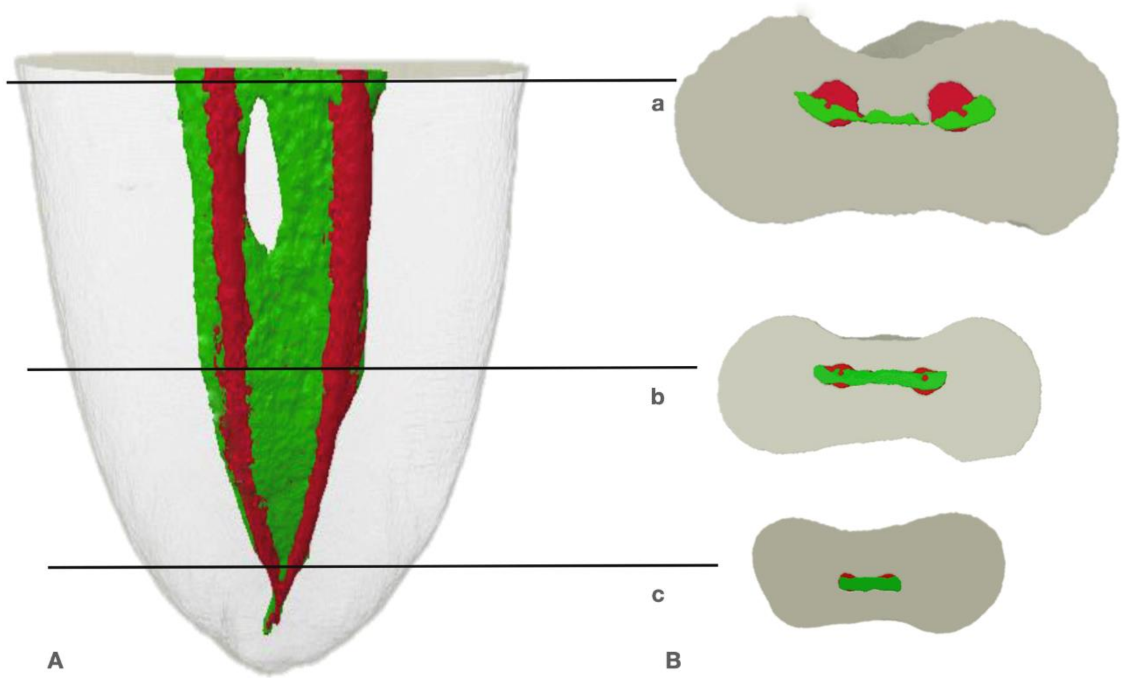

Fig. 8. Representative 3D micro-computed tomography (micro-CT) reconstruction of a tooth with Traditional Access Cavity (TradAC) taken before (green) and after (red) of the root canal preparation with RACE® R MOTION system(FKG Dentaire Swiss Endo, La Chaux-de-Fonds, Switzerland) showing unprepared areas (green). (B) Representative transverse sections of cervical (a), middle (b) and apical (c) thirds showing unprepared areas (green).

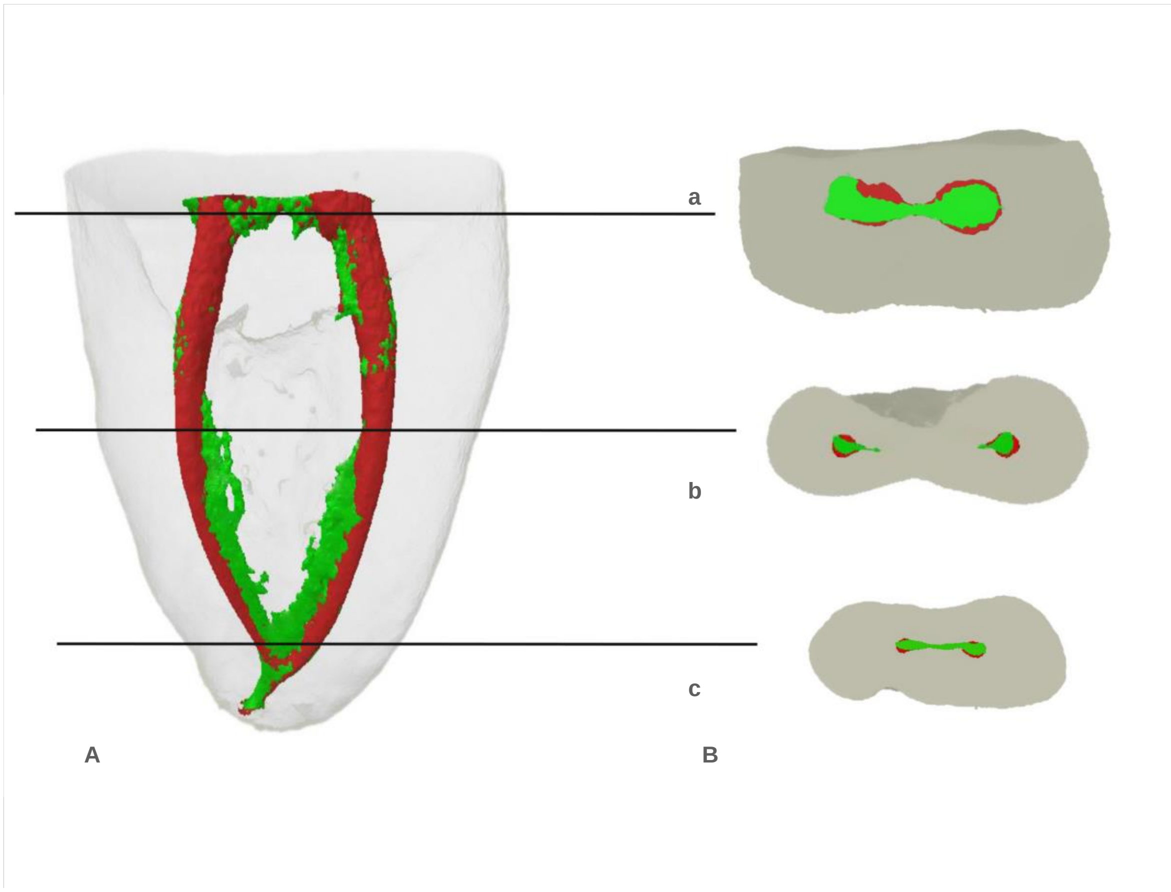

Fig. 9. Representative 3D micro-computed tomography (micro-CT) reconstruction of a tooth with Conservative Access Cavity (ConsAC) taken before (green) and after (red) of the root canal preparation with the RACE® R MOTION system (FKG Dentaire Swiss Endo, La Chaux-de-Fonds, Switzerland), showing unprepared areas (green). (B) Representative transverse sections of cervical (a), middle (b) and apical (c) thirds, showing unprepared areas (green).

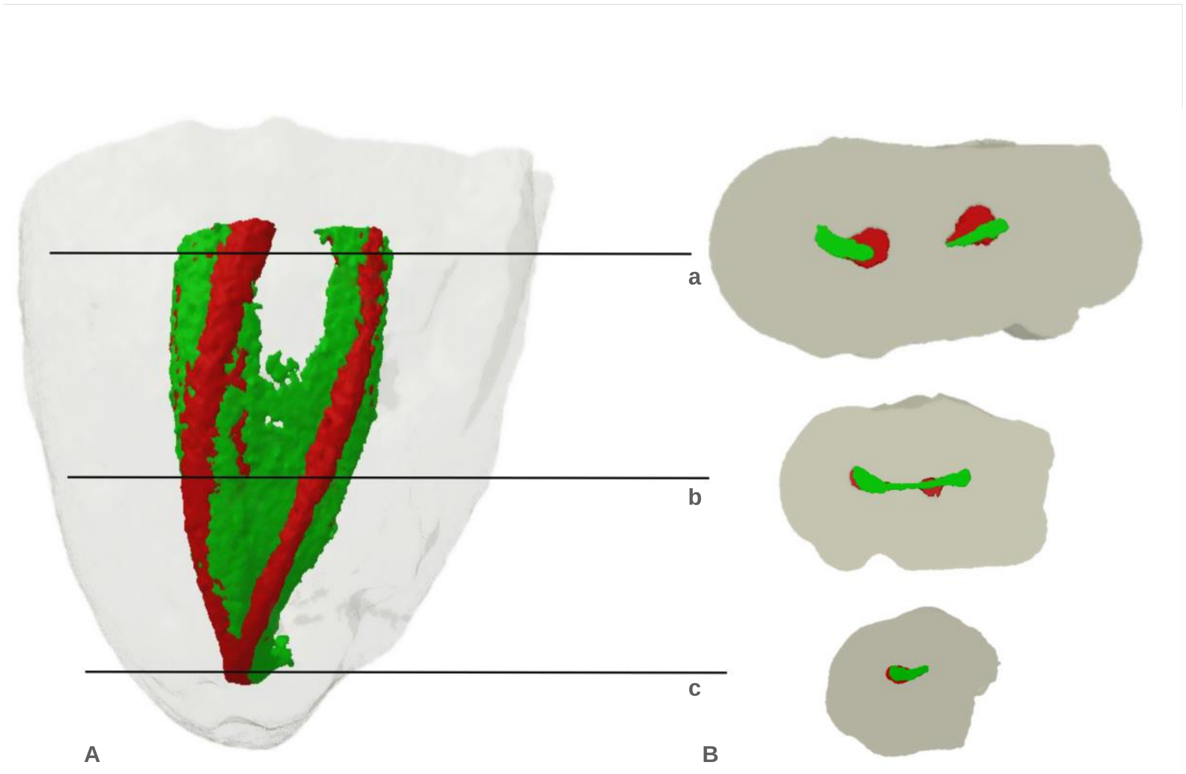

Fig. 10. Representative 3D micro-computed tomography (micro-CT) reconstruction of a tooth with Ultraconservative Access Cavity (UltraAC) taken before (green) and after (red) of the root canal preparation with RACE® R MOTION system (FKG Dentaire Swiss Endo, La Chaux-de-Fonds, Switzerland) showing unprepared areas (green). (B) Representative transverse sections of cervical (a), middle (b) and apical (c) thirds, showing unprepared areas (green).

Intragroup analysis

In the traditional access group, canal volume, area and Structure Model Index (SMI) values increased significantly after preparation ($P > 0.05$). In the conservative access group, the volume and SMI increasement were within the statistical significance level ($p=0.05$), but there was not significance for the area increase ($P > 0.05$). In the ultraconservative group, there were not significant differences in the canal volume, area and SMI values ($P > 0.05$) (Table 2).

TABLE 2. SMI of mesial root canals in mandibular molars before and after preparation

ACCESS CAVITY		Mean ± SD	Median	Range
TRADITIONAL.	Initial	2.222	2.39	1.78 – 2.76
	Final	2.675	2.35	2.12 – 3.52
CONSERVATIVE.	Initial	2.008	2.1	1.19 -2.71
	Final	2.4	2.56	1.83 – 2.82
ULTRACONSERVATIVE	Initial	2.13	2.15	1.27 -3.48
	Final	2.338	2.56	1.5 – 2.56

7. DISCUSSION

This study used a micro-CT approach to assess the canal shaping ability in mesial roots of mandibular molars, conditioned by the preparation of 3 different types of access cavities (traditional, conservative, and ultraconservative).

The outcome of the endodontic treatment is mostly reliant upon the effectiveness of chemomechanical procedures. These in turn can be influenced by the design of the access cavity. There can be negative consequences on treatment prognosis if there is not an appropriate disinfection of the root canal (SIQUEIRA 2001). Although only a few studies have evaluated these parameters, there seems to be some concerns about the irrigation efficacy, the canal debridement, and the pulp tissue remain material in teeth that had the access cavities prepared with minimally invasive designs. Generally, minimally invasive access cavities in posterior teeth provide a curved path for endodontic instruments to enter the canal and reach the apical area, instead of a straight-line access achieved with the traditional coronal access. Therefore, it can potentially lead to increased risk of canal transportation and iatrogenic errors (KRISHAN et al 2014, NEELAKANTAN et al 2018, ALOVISI et al. 2018).

The main purpose of minimally invasive preparations is to improve the resistance to fracture of endodontically treated teeth. However, this hypothesis has not been comproved in most studies that evaluated anterior teeth, despite preserving more dental structure (KRISHAN et al. 2014, ÖZKURT-KAYAHAN & KAYAHAN 2016, D'AMICO et al. 2019, ROVER et al. 2020). In contrast to posterior teeth, there were discrepancies between the different studies (KRISHAN et al. 2014, MOORE et al. 2016, ROVER et al. 2017, PLOTINO et al. 2017, SABETI et al. 2018, CORSENTINO et al. 2018, MAKATI et al. 2018, ÖZYÜREK et al. 2018, ABOU-ELNAGA et al. 2019, ZHANG et al. 2019, BARBOSA et al. 2020, AUGUSTO et al. 2020, SABERI et al. 2020, SILVA et al. 2020 A, XIA et al. 2020).

Previously, only a few studies have been carried out with fresh, recently extracted teeth (MARKVART et al. al. 2012, LACERDA et al. 2017, SIQUEIRA et al. 2018, ALOVISI et al. 2018, NEELAKANTAN et al. 2018). In this study, all the fresh tooth specimens were kept frozen in saline solution before use, unlike other authors who placed the samples in neutral buffered formalin until micro-CT scan for post-prep analysis (SIQUEIRA et al. 2018 and LACERDA et al. 2017).

Micro-CT is a non-destructive method that has been used to compare root canal morphology before and after preparation in extracted teeth (SIQUEIRA et al. 2018). It has recently been suggested that anatomical matching using micro-CT technology is the best method to control the confounding effect that anatomical variation in tooth morphology can have on the results of matched pairs design experiments (DE-DEUS et al. 2020). Although micro-CT evaluation is not clinically applicable, clinicians can use small field of view CBCT images to plan conservative chamber access schemes in the clinical practice (BÓVEDA et al. 2012).

To provide a proper comparison between the different access groups, teeth should be matched for root canal size and volume using micro-computed tomography imaging (ROVER et al. 2017, NEELAKANTAN et al. 2018, ROVER et al. 2020 and SHABBIR et al. 2021). This methodology has been implemented in most of the studies that investigate canal geometry (SIQUEIRA et al. 2013, KRISHAN et al.

2014, AZIM et al. 2017, ROVER et al. 2017, NEELAKANTAN et al. al 2018, BARBOSA et al. 2020, WEBBER et al. 2020, VIEIRA et al. 2020 and ROVER et al. 2020). The evaluation by micro-CT confirmed the normal sample distribution between groups regarding anatomic aspects, volume, and surface of the root canal space (SIQUEIRA et al. 2013, AZIM et al. 2017, ROVER et al. 2017, ROVER et al. 2020 and WEBBER et al. 2020).

Considering the intrinsic heterogeneity of root canal anatomy, which is a known bias for comparative studies, many efforts were made to ensure samples comparability respecting root canal anatomy. To do so, sample matching of specimens was based on their anatomical and morphological configuration (volume, surface area and 3D configuration) using micro-CT technology. As with this study, this procedure was performed by other authors (SIQUEIRA et al. 2013, AZIM et al. 2017, ROVER et al. 2017, AUGUSTO et al. 2020, SILVA et al.2020 A and ROVER et al. 2020).

Many micro-CT studies have demonstrated the high occurrence of unprepared areas after using virtually any instrument and instrumentation technique (PETERS et al. 2001, PAQUÉ et al. 2005, SIQUEIRA et al. 2013, VERSANI et al. 2013, ROVER et al. 2017, SIQUEIRA et al. 2018, SILVA et al. 2020 A, VIEIRA et al. 2020, PÉREZ et al. 2020). Inferences have been made about the possible retention of pulp tissue remains and bacterial biofilm on unprepared walls (SIQUEIRA et al. 2013 and ZHAO et al. 2014). However, this is the first study to evaluate the actual conditions of these unprepared canal walls on micro-CT images. The analysis of unprepared surfaces can only be performed through a correlative approach using different techniques, such as histological evaluation (SIQUEIRA et al. 2018).

An important parameter evaluated in micro-CT studies is the amount of unprepared canal surface; studies have revealed that approximately 10% to 50% of the main root canal surfaces remain unprepared after different instruments were used (PAQUÉ et al. 2011 B, MARKVART et al. 2012, SIQUEIRA et al. 2013, PETERS et al. 2015 and SIQUEIRA et al. 2018). In clinical circumstances, if there is a large unprepared area it may be difficult to control infection (MARKVART et al. 2012).

As with other investigations, mandibular molars were used in this study (MARKVART et al. 2012, SIQUEIRA et al. 2013, ZHAO et al. 2014, PETERS et al. 2015, LACERDA et al. 2017, SIQUEIRA et al. 2018, NEELAKANTAM et al. 2018, ALOVISI et al. 2018, WEBBER et al. 2020, AUGUSTO et al. 2020 and BARBOSA et al. 2020). Mesial roots of mandibular molars were used because they present a high complexity degree, making it difficult to achieve optimal results in terms of antibacterial ability and mechanical preparation. Many areas of the main root canal were left unprepared, regardless of the instrumentation technique used, rang of fing from 20% to 35% (isthmus area excluded) (SIQUEIRA et al. 2013, ZHAO et al. 2014).

This investigation is the first study that compares the action of 3 different types of coronal accesses (traditional, conservative and ultra- conservative) in the shaping of root canals in mandibular molars. Previous studies have compared traditional, conservative, and direct accesses (BARBOSA et al. 2020), traditional versus conservative accesses (KRISHAN et al. 2014, MOORE et al. 2016, ROVER et al. 2017, and ALOVISI et al. 2018) and traditional versus ultra-conservative accesses (SILVA et al. 2020 A and ROVER et al. 2020) and traditional versus direct access (ultraconservative) chamber accesses (NAAELAKANTAL et al. 2018).

The initial sample consisted of 55 specimens, 10 of which were excluded due to anatomical characteristics and severe calcification of the root canal. There was no instrument fracture during the mechanical root canals preparation, but there was plastic deformation of an instrument during its first use. Additionally, there was a fracture of a manual instrument, a #10 K file-type, during the root canal patency stage of one (1) specimen. The root canal patency could not be obtained in five of those teeth. The experimental groups consisted of 13 specimen each. However, the final sample for this investigation was made up of 70 mesial root canals of 35 fresh mandibular molars with vital pulps, (10 TradAC,13 ConsAC, 12 UltraAC), discarding 3 teeth from the TraAC group and 1 tooth from the UltraAC group in the sample processing stage. This sample is similar to that reported in a previous investigation, which included root canals of 10 fresh mandibular premolars with necrotic pulp and apical periodontitis and the mesial root canals of 11 mandibular molars with vital pulps (SIQUEIRA et al. 2018). Another study carried out a similar selection to the one present in this study, in which 33 distal roots of fresh mandibular molars with vital pulps were used, while the mesial roots functioned as controls (LACERDA et al. 2017).

The instrumentation efficacy was evaluated using high-resolution micro-CT images, similar to previous studies (ZHAO et al. 2014, VERSIANI et al. 2016, ALAVOSI et al. 2017, SABERI et al. 2017). This technology allows scanning the canal before and after instrumentation, verifying changes in root canal anatomy, such as the non-instrumented canal areas (DE-DEUS et al. 2015, VERSIANI et al. 2016, AMOROSO-SILVA et al. al. 2017), and the volume of dentin removed. Uninstrumented canal areas can be colonized by biofilms and serve as a potential cause of persistent infection, which can compromise the treatment outcome (SIQUEIRA et al. 2018).

The present findings showed that through micro-CT analysis, the average number of areas that remained unprepared with the 3 types of chamber accesses ranged from 16.60% (ConsAC), 12.94% (TradAC) and 31.27% (UltraAC) in the total canal length. A previous study stated that the average percentages of the uninstrumented canal area in TradAC and ConsAC in maxillary molars were 25.8% and 27.4%, respectively, comprising similar values to those obtained (ROVER et al. 2017).

The results of this study suggest that there is a significant difference between UltraAC group with respect to TradAC and ConsAC groups ($P < 0.05$), being similar to previous studies that show a statistically significant difference in unprepared walls in root canals with TradAC compared to ConsAC (KRISHAN et al. 2014, XIA et al. 2020), and TradAC compared to ConsAC and truss access cavities (BARBOSA et al. 2020). In contrast, there are studies that show that no significant differences regarding the number of unprepared walls between TradAC and ConsAC (MOORE et al. 2016, ROVER et al. 2017 and SILVA et al. 2020 A), and TradAC vs. UltraAC (ROVER et al. 2020).

Ten studies which evaluated the amount of unprepared areas within the root canal space were identified. Four studies on anterior teeth (MANNAN et al. 2001, KRISHAN et al. 2014, ROVER et al. 2020, VIEIRA et al. 2020.) and only 1 study compared TradAC and ConsAC, and showed that ConsAC had the highest proportion of the instrumented root canal surface. On the other hand, TradAC had worse results. However, the study used ink to compare touched and untouched surfaces, and there was not a standardization in terms of canal volume before instrumentation (MANNAN et al. 2001). In studies that used micro-CT images for evaluation (3 studies) (KRISHAN et al. 2014, ROVER et al. 2020, VIEIRA et al. 2020.), no significant differences were found between traditional and conservative access preparations. In posterior teeth (7 studies), there was disagreement between the studies. Four studies showed no differences (MOORE et al. 2016, ROVER et al. 2017, SILVA et al. 2020 A, AUGUSTO et al. 2020) and the other 3 favored traditional accesses to affect more canal walls (KRISHAN et al. 2014, BARBOSA et al. 2020, XIA et al.2020). Straight-line access allows the instrumentation of the greatest proportion of the root canal wall (MANNAN et al. 2001), that is why, in anterior teeth, conservative and ultra-conservative access cavity occurs straight-line access to RCS, unlike, in posterior teeth, only straight-line access to RCS occurs in traditional access cavity.

The average unprepared canal area was 17.32% (average, 16.60) for the ConsAC group, 13.55% (average, 12.94) for TradAC, and 31 .40% (average, 31.27) for the UltraAC, with significant differences between ultraconservative group and others (P < 0.05). The average unprepared surface area after reciprocating instrument preparation of the mesial canals of mandibular molars with vital pulps was within the observed range in other studies performed on mandibular molars (SIQUEIRA et al. al. 2013 (20.7%) BUSQUIM et al. 2015 (9.73%-15.12%), GERGI et al. 2015 (20.55%-35.31%), and SIQUEIRA et al. 2018 (18.1%)).

Regarding the increase in canal volume, the average percentage with root canal preparation was 45.62% (average, 36.16) for the ConsAC group, 50.14% (average, 55.92) for the TradAC group, and 22.42% (average, 24.58) for the UltraAC group, with a significant difference between UltraAC and TradAC (P < 0.05). In contrast, previous studies did not report a significant difference between their 4 study groups with TradAC vs UltraAC (ROVER et al. 2020) and between TradAC and ConsAC groups (P < 0.05) (XIA et al. 2020).

The average increase percentage in canal area with root canal preparation was

27.05% (average, 11.08) for the ConsAC group, 30.68%(average, 23.02) for TradAC, and 3.83% (average, 3.46) for UltraAC, with significant differences between UltraAC and TradAC ($P < 0.05$). These results are consistent with previous studies, which report that the amount of dentin removed was significantly lower from a statistical point of view ($P < 0.003$) in the conservative chamber access group compared to the traditional chamber access group for all tooth types (KRISHAN et al. 2014, ALOVISI et al. 2018, XIA et al. 2020).

No statistically significant difference has been reported between the traditional versus conservative access cavity groups (ROVER et al. 2017). Other authors did not show significant differences between the different access groups either, with values of 2.52% for TradAC, 2.22% for ConsAC, and 2.19% for truss access cavities (BARBOSA et al. 2020).

Several authors conclude that few benefits have been shown with the minimally invasive premise, which focuses primarily on preserving more tooth structure of the crown portion and potentially minimizing stresses on the pericervical dentin (ROVER et al. 2017 and SHABBIR et al. 2021). In addition, the minimally invasive concept has not been translated into a consistent improvement in the fracture resistance of root canal-treated teeth. Actually, there are concerns associated with minimally invasive techniques regarding disinfection, procedural errors, tooth discoloration, and prolonged operating time (SHABBIR et al 2021, VIEIRA et al 2020).

The morphometric parameter Structure Model Index (SMI) allows to evaluate the appearance of the root canal cross-section as round or more ribbon-shaped, with values ranging from 1 (parallel plates) to 4(perfect ball) (PAQUÉ et al. 2011 A). In this study, the SMI values of the mesial root canals of mandibular molars varied depending on the type of accesses, i.e. TradAC = 2.22 - 2.68, ConsAC = 2.01 - 2.4 and UltraAC = 2.13 - 2.34 (initial-final, respectively). Similar results were reported in another study, presenting SMI values of 2.72 (rod-like structures) for all maxillary molar canals (2.97 palatine, 2.68 distobuccal and 2.51 mesiobuccal) with traditional access cavities (PETER et al. 2000). In contrast, SMI values in distal canals of mandibular molars of 0.74 and 0.66 have been reported for canals prepared with SAF files (20 um and 34 um) and 0.57 with rotary files (plate-like structures), in samples with traditional coronal accesses (PAQUÉ et al. 2011 A).

The results of this study indicated that the ultraconservative access design resulted in more unprepared surface areas; with a lower percentage of the canal area increase in the entire canal, compared to the traditional and conservative accesses, with a significant difference between the ultraconservative group and the other two. This finding rejects the null hypothesis(H_0) in which the different endodontic approach designs do not influence the shaping of root canal systems. It also partially rejects the alternative hypothesis (H_1), in which the conservative and ultra-conservative endodontic approaches could negatively influence the root canal shaping.

It is important to point out that this study only evaluated the influence of the access cavity on root canal shaping. It is necessary to carry out other studies which evaluate the cleaning and disinfection of the root canal system, which are factors directly related to the success of root canal treatment.

8. CONCLUSION

Ultraconservative access cavities did not offer any advantage compared to traditional and conservative endodontic cavities in any of the shaping parameters considered. The latter two, in turn, showed no significant differences in the parameters evaluated. Future studies should use a correlative approach to assess the influence of access cavity designs on the cleaning, shaping, and disinfection effects of preparation in infected root canals.

9. BIBLIOGRAPHIC REFERENCES

- Abou-Elnaga M., Alkhawas M., Kim H., Refai A. (2019). Effect of truss accessand artificial truss restoration on the fracture resistance of endodontically treated mandibular first molars. J Endod. 45, 813–817.
- Alovisi M., Pasqualini D., Musso E., Bobbio E., Giuliano C., Mancino D., ScottiN., Berutti E. (2018). Influence of contracted endodontic acces on root canal geometry: an in vitro study. J Endod. 44 (4), 614-620.
- Amoroso-Silva P., Alcalde M., Hungaro Duarte M., De-Deus G., Ordinola-Zapata R., Freire L., Cavenago B., De Moraes I. (2017). Effect of finishing instrumentation using NiTi hand files on volume, surface area and uninstrumented surfaces in C- shaped root canal systems. Int Endod J.; 50: 604–611.
- Azim A., Piasecki L., da Silva Neto U., Cruz A., Azim K (2017). XP Shaper, a novel adaptive core rotary instrument: micro-computed tomographic analysis of its shaping abilities. J Endod.; 43 (9): 1532-1538.
- Augusto C., Barbosa A., Guimaraes C., Lima C., Ferreira C., Sassone L., Silva E. (2020). A laboratory study of the impact of ultraconservative access cavities and minimal root canal tapers on the ability to shape canals in extracted mandibular molars and their fracture resistance. Int Endod J.; 53: 1516–1529.
- Barbosa A., Silva E., Coelho B., Ferreira C., Lima C., Sassone L. (2020). The influence of endodontic access cavity design on the efficacy of canal

instrumentation, microbial reduction, root canal filling and fracture resistance in mandibular molars. Int Endod J.; 53: 1666–1679.

- Bóveda C., Lopez J., Clavel T. (2012) Cone Beam Computed Tomography-CBCT. En https://www.carlosboveda.com/tvd.htm
- Bóveda C., Kishen A. (2015). Contracted endodontic cavities: the foundation for less invasive alternatives in the management of apical periodontitis. Endod Topics. 33: 169–86.
- Busquim S., Cunha R., Freire L., Gavini G., Machado M., Santos M. (2015). A micro- computed tomography evaluation of long-oval canal preparation using reciprocating or rotary systems. Int Endod J.; 48: 1001-1006.
- Clark D., Khademi J. (2010). Modern molar endodontic access and directed dentin conservation. Dent Clin N Am. 54, 249–273.
- Corsentino G., Pedullà E., Castelli L., Liguori M., Spicciarelli V., Martignoni M., Ferrari M., Grandini S (2018). Influence of access cavity preparation and remaining tooth substance on fracture strength of endodontically treated teeth. J Endod. 44, 1416–21.
- D'Amico Y., Silva-Neto U., Westphalen V., Carneiro E., Kowalczuck A. (2019). Fracture strength of teeth with access cavity preparation with operating microscope or on buccal surfaces. Braz Dent Sci.; 22 (1): 88-93.
- De-Deus G., Belladonna F., Silva E., Marins M., Souza E., Perez R., Lopes R., Versiani M., Paciornik S., NevesA. (2015). Micro-ct evaluation of non-instrumented canal areas with different enlargements performed by niti systems. Braz Dent J.; 26: 624–629.
- De-Deus G., Simõe-Carvalho M., Belladonna F., Versiani M., Silva E.,

Cavalcante D., Souza E., Johnsen G., Haugen H., Paciornik S. (2020). Creation of well- balanced experimental groups for comparative endodontic laboratory studies: a new proposal bases on micro-CT and in silico methods. Int Endod J.; 53: 974-985.

- Gergi R., Osta N., Bourbouze G., Zgheib C., Arbab-Chirani R., Naaman A. (2015). Effects of three nickel titanium instrument systems on root canal geometry assessed by micro- computed tomography. Int Endod J.; 48: 162-170.
- Kishen A. (2015). Biomechanics of fractures in endodontically treated teeth.Endod Topics. 33: 3–13.
- Krishan R., Paqué F., Ossareh A., Kishen A., Dao T., Friedman S (2014). Impacts of conservative endodontic cavity on root canal instrumentationefficacy and resistance to fracture assessed in incisors, premolars, andmolars. J Endod. 40, 1160–6.
- Lacerda M., Marceliano-Alves M., Pérez A., Provenzano J., Neves M., PiresF., Gonçalves L., Rô ças I. Siqueira J (2017). Cleaning and shaping oval canals with 3 instrumentation systems: a correlative micro-computed tomographic and histologic study. J Endod. 43 (11): 1878-1884.
- Makati D., Shah N., Brave D., Rathore V., Bhadra D., Dedania M (2018). Evaluation of remaining dentin thickness and fracture resistance ofconventional and conservative access and biomechanical preparation inmolars using cone-beam computed tomography: An in vitro study. J ConservDent. 21 (3): 324-327.
- Mannan G., Smallwood E., Gulabivala K. (2001). Effect of access cavity location and design on degree and distribution of instrumented root canal surface in maxillary anterior teeth. Int Endod J.; 34:176–183.

- Markvart M., Darvann T., Larsen P., Dalstra M., Kreiborg S., Bjørndal L (2012). Micro-CT analyses of apical enlargement and molar root canal complexity. Int Endod J. 45: 273-281.
- Moore B., Verdelis K., Kishen A., Dao T., Prostho D., Friedman S (2016). Impacts of contracted endodontic cavities on instrumentation efficacy and biomechanical responses in maxillary molars. J Endod. 42:1779–1783.
- Neelakantan P., Khan K. Hei G., Yip C., Zhang C., Cheung G. (2018). Does the orifice-directed dentin conservation access desing debride pulp chamber and mesial root canal systems of mandibular molars similar to a traditional access desing?. J Endod.; 44: 274-279.
- Niemi T., Marchesan M., Lloyd A., Seltzer R. (2016). Effect of instrument design and access outlines on the removal of root canal obturation materials in oval-shaped canals. J Endod. 42: 1550–4.
- Olejniczak A., Grine F. (2006). Assessment of the accuracy of dental enamel thickness measurements using microfocal x-ray computed tomography. Anat Rec. 288: 263-275.
- Özkurt-Kayahan Z., Kayahan M. (2016). Fracture resistance of prepared maxillary incisor teeth after different endodontic access cavity location. Biomed Res. 27 (1): 191-194.
- Özyürek T., Ülker O., DemiryüreK O., Yilmaz F. (2018). The effects ofendodontic access cavity preparation design on the fracture strength ofendodontically treated teeth: traditional versus conservative preparation. J Endod. 44, 800–5.

- Paqué F., Barbakow F., Peters O (2005). Root canal preparation with endo- eze aet: changes in root canal shape assessed by micro-computed tomography. Int Endod J. 38: 456-464.
- Paqué F., Peters O. (2011 A). Micro–computed tomography evaluation of the preparation of long oval root canals in mandibular molars with the self-adjusting file. J Endod.; 37: 517–521.
- Paqué F., Zehnder M., De-Deus G (2011 B). Microtomography-based comparison of reciprocating single-file F2 ProTaper technique versus rotary full sequence. J Endod. 37: 1394-1397.
- Pérez A., Ricu cci D., Vieira G., Provenzano J., Alves F., Marceliano-Alves M., Rôças I., Siqueira J (2020). Cleaning, shaping, and disinfecting abilities of 2 instrument systems as evaluated by a correlative micro-computed tomographic and histobacteriologic approach. J Endod. 46 (6): 846-857.
- Peters O., Laib A., Rü egsegger P., Barbakow F. (2000). Three-dimensional analysis of root canal geometry by high-resolution computed tomography. J Dent Res.; 76 (6): 1405-1409.
- Peters O., Schö nenberger K., Laib A (2001). Effects of four ni-ti prreparation techniques on root canal geometry assessed by micro computed tomography.Int Endod J. 34: 221-230.
- Peters O., Arias A., Paqué F (2015). A micro-computed tomographic assessment of root canal preparation with a novel instrument, TRUShape, inmesial roots of mandibular molars. J Endod. 41: 1545-50.

- Plotino G, Grande N, Isufi A, Ioppolo P. Pedullà E, Bedini R, Gambarini G, Testarelli L (2017). Fracture strength of endodontically treated teeth with different access cavity designs. J Endod. 43: 995–1000.
- Roperto R., Sousa Y., Dias T., Machado R., Perreira R., Leoni G., Palma- Dibb R., Rodrigues M., Soares C., Teich S., Sousa-Neto M (2019). Biomechanical

behavior of maxillary premolars with conservative and traditional endodontic cavities. Quintessence Int. 50 (5): 350–6.

- Rover G., Belladonna F., Bortoluzzi E., De-Deus G., Silva E. Texeira C (2017). Influence of access cavity desing on root canal detection,instrumentation efficacy, and fracture resistance assessed in maxillary molars. J Endod. 43: 1657-1662.
- Rover G., Lima C., Belladonna F., Garcia L., Bortoluzzi E., Silva E., Teixeira C. (2020), Influence of minimally invasive endodontic access cavities on root canal shaping and filling ability, pulp chamber cleaning and fracture resistance of estracted human mandibular incisors. Int Endod J.; 53 (11): 1530-1539.
- Saberi E., Pirhaji A., Zabetivan F (2020). Effects of endodontic access cavitydesign and thermocycling on fracture strength of endodontically treated teeth.Clin, Cosmet Investig Dent. 23, 149–56.
- Sabeti M., Kazem M., Dianat O., Bahrololumi N., Beglou A., Rahimipour K., Dehnavi F (2018). Impact of access cavity desing and root canal taper on fracture resistance of endodontically treated teeth: an ex vivo investigation. J Endod. 44 (9): 1402-1406.
- Saygili G., Uysal B., Omar B., Ertas E., Ertas H. (2018). Evaluation of relationship between endodontic access cavity types and secondary mesiobuccal canal detection. BMC Oral Health. 18: 121-126.
- Shabbir J., Zehra T., Najmi N., Hasan A., Naz M., Piasecki L., Azim A (2021). Access cavitypreparations: classification and literature review of traditional and minimally invasive endodontic access cavity designs. J Endod.; 47: 8, 1229- 1244.

- Silva E., Rover G., Belladonna F., De-Deus G., Texeira C., Fidalgo T (2018). Impact of contracted endodontic cavities on fracture resistance of endodontically treated teeth: a systematic review of in vitro studies. Clin Oral Investig. 22: 109–18.
- Silva A., Belladonna F., Rover G., Lopes R., Moreira E., De-Deus G., Silva E (2020 A). Does ultraconservative access affect the efficacy of root canal treatment and the fracture resistance of two-rooted maxillary premolars? Int Endod J. 53: 265–75.
- Silva E., Pinto k., Ferreira C., Belladona F., De-Deus G., Dummer P., VersianiM. (2020 B). Current status on minimal Access cavity preparations: a critical analysis and a proposal for a universal nomenclature. Int Endod J. 53: 1618- 1635.
- Silva E., Lima C., Barbosa A., Augusto C., Souza E., Lopes R., D-Deus G., Versiani M (2021). Preserving dentine in minimally invasive access cavities doesnot strength fracture resistance of restored mandibular molars. Int Endod J. 54 (6): 966- 974.
- Siqueira J. (2001). Aetiology of root canal treatment failure: why well-treated teeth can fail. Int Endod J. 34 (1): 1-10.
- Siqueira J., Rôças I (2008). Clinical implications and microbiology of bacterial persistence after treatment procedures. J Endod. 34,1291–301.
- Siqueira J., Alves F., Versiani M. Rôças I., Almeida B., Neves M., Sousa-Neto M. (2013). Correlative bacteriologic and micro- computed tomographic analysisof mandibular molar mesial canals prepared by Self- Adjusting file, Reciproc, and Twisted File systems. J Endod. 39: 1044-50.
- Siqueira J., Perez A., Marceliano-Alves M., Provenzano J., Monteros S., Pires F., Vieira G., Rôças I., Alves F (2018). What happens to unprepared root canal walls: a correlative analysis using micro-computed tomography and histology/scanning electron microscopy. Int Endod J. 51 (5): 501-508.

- Swain M., Xue J (2009). State of the art of micro-ct applications in dental research. Int J Oral Sci. 1 (4): 177-188.
- Versiani M., Leoni G., Steier L., De-Deus G., Tassani S., Pé cora J., Sousa- NetoM (2013). Micro-computed tomography study of oval-shaped canals prepared with the self-adjusting file, reciproc, wave one, and protaper universal systems. J Endod. 39: 1060-1066.
- Versiani M., Alves F., Andrade-Junior C., Marceliano-Alves M., Provenzano J., Rô ças I., Sousa-Neto M., Siqueira J. (2016). Micro-CT evaluation of the efficacy of hard-tissue removal from the root canal and isthmus area by positive and negative pressure irrigation systems. Int Endod J.; 49:1079–1087.
- Vertucci F., Haddix J (2011). Morfologia del diente y preparació n de la cavidad de acceso. In: Hargreaves K., Cohen S., Berman L (eds). Vías de la Pulpa. Barcelona, España: ASM Press136-222.
- Vieira G., Perez A., Alves F., Provenzano J., Mdala I., Siqueira J., Rôças I (2020). Impact of contracted endodontic cavities on root canal disinfection and shaping. J Endod.; 46, 655–61.
- Webber M., Piasecki L., Jussiani E., Andrello A., dos Reis P., Azim K., Azim A (2020). Higher speed and no glide path: a new protocol to increase the efficiencyof XP Shaper in curved canals- an in vitro study. J Endod.; 46 (1): 103-109.
- Xia J., Wang W., Li Z., Lin B., Zhang Q., Jiang Q., Yang X. (2020). Impacts of contracted endodontic cavities compared to traditional endodontic cavities in premolars. BMC Oral Health; 20:250.

- Zhang Y., Liu Y., She Y., Liang Y., Xu F., Fang C (2019). The effect ofendodontic access cavities on fracture resistance of first maxillary molar using the extended finite elemento method. J Endod.; 45: 316-321.
- Zhao D., Shen Y., Peng B., Haapasalo M. (2014). Root canal preparation of mandibuar molars with 3 nickel-titanium rotary instruments: a micro-computed tomographic study. J Endod.; 40 (11): 1860-1864.