ORIGINAL ARTICLE

EVALUATION OF THE QUANTITY AND VOLUME OF TOOTH SUBSTANCE LOSS AFTER CONSERVATIVE ACCESS CAVITIES AND ROOT CANAL SHAPING ON DIFFERENT TYPES OF HUMAN TEETH-AN IN VITRO STUDY

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ABSTRACT

Objective. The aim of the present study was to assess the quantity and the volume of tooth substance loss after access cavity and root canal shaping on three groups of human extracted teeth (incisors, premolars and molars) by weighting and by digital scanning.
Material and Methods. 19 human teeth divided in 3 groups: Group 1 Molars, Group 2 Incisors and Group 3 Premolars were endodontically treated and using a digital scale, their weight in grams was recorded before and after each endodontic procedure (access cavity and root canal shaping), with a precision of 0.001g. The tooth substance loss after each step was calculated as a difference. A chairside intraoral scanner Planmeca PlanScan (Planmeca, Helsinki, Finland) was used to scan the tooth surfaces corresponding to the access cavities before and after the root canal treatment. The obtained images were recorded in the Planmeca Romexis software and the area and volume of tooth substance loss was calculated.
Results. The total tooth substance loss varied between 0.017 and 0.213g and as percentage between 2.53% and 9.48%. The total area loss varied between 3 and 23 mm2. Minimal amount of tooth substance and area removal was recorded in incisors.
Conclusions. The tooth substance loss by creating conservative access cavities and using modern nickel-titanium instruments in root canal shaping is minimal. Digital scanning is an accessible method in evaluating the total area lost during endodontic procedures.
Keywords: conservative access cavity, digital scanning, tooth substance loss.

INTRODUCTION

The survival rate of teeth with endodontic treatment is comparatively lower than of teeth with vital pulp. From far, the most frequent cause of their extraction is correlated with their restorability [1-3]. It is well known that the long-term success of endodontic therapy is directly influenced by the quality of the coronal restoration [4-6] and an inadequate coronal restoration can be a source of microleakage and failure of the endodontic therapy [7, 8].

Although there are many recommendations based on the clinical experience, only a few studies tried to evaluate the impact of the remaining tooth structure on the survival rate of endodontically treated teeth. Some of them aimed to classify the quantity of the remaining tooth structure, expressed as a percentage of remaining volume, without defining how this volume was measured [9, 10]; others are using a more generically term, substantial loss of tooth structure, or are defining a minimal necessary dentinal height for restorability [11, 12]. In other studies, in teeth with mesial or distal caries, terms like cuspal protection and minimal dentinal loss are described [13].

In vivo studies associated the medium and long-term survival rate of teeth with endodontic treatment with the number of remaining walls of the access cavity, the presence of the ferrule effect [14-16] or with the height of the coronal dentinal walls before the restoration and prosthetic preparation for a crown [12]. None of these methods evaluated in a reproducible way the quantitative loss of the tooth structure.

Recent developments in digital dentistry with 3D virtual models of patients' dentition are able to scan and capture direct images of teeth and soft tissues, digital scanning being more and more used in dentistry [17-19]. The accuracy of linear measurements obtained with intraoral scanners has been demonstrated [20]. Also, the use of cone beam computed tomography has overpassed the limits of the 2D images obtained by dental radiographies [21], allowing a more precise evaluation of the dental structure volume loss after the endodontic therapy, and mainly after the access cavity.

Major modifications in the biomechanics of teeth with endodontic treatment are caused by the loss of tooth structure as a consequence of pre-existent conditions (carious lesions, fractures, cavity

preparations), of endodontic treatment (access cavity preparation or root canal shaping), or of other invasive procedures (post or core preparation for the coverage with a prosthetic crown) [22-24]. All these factors contribute to a significant removal of coronal and radicular tooth structure, reducing the resistance of teeth and increasing their fracture risk. During access cavity preparation, the major part of the dentin overlaying the pulp chamber is removed, in order to favor the endodontic treatment and the access to the root canal, but with possible dramatic consequences of the tooth resistance [23]. Deeper the access cavity is, especially in mesio-occluso-distal cavities, higher the fracture risk; that is why, these teeth have to be restored with cuspal protection, in order to prevent their fracture under occlusal forces [24].

Aim of the study

The aim of the present study was to evaluate on different types of extracted human teeth, the amount of tooth structure loss after conservative access cavity and root canal shaping procedures, expressed as quantity in grams, and as areas and volumes loss measured on digital models.

MATERIAL AND METHODS

Nineteen recently extracted human teeth with sound tooth structure were included in the present study, distributed in three groups, according to their morphological type: Group 1 Molars (n=7), Group 2 Incisors (n=8)-(7 lowers and 1 central upper) and Group 3 Premolars (n=4). Inclusions criteria were no coronal restorations, free of caries, no endodontic treatment, and completely formed roots. Teeth were fixed in a reproducible vertical position during examination in a prefabricated silicone key (Zetaplus, Zhermack, Badia Polesine, Italy) and were initially evaluated on a CBCT to confirm the integrity of the coronal and radicular structure and the absence of a former endodontic treatment.

The lingual surfaces of the incisors and the occlusal for molars and premolars were digitally scanned with a chairside intraoral scanner from Planmeca PlanScan (Planmeca, Helsinki, Finland) in the department of Prosthodontics; the resulting digital models were saved and later on used in the assessment of tooth structure loss.

In the Endodontics department, each tooth was weighted with a precision electronical balance Partner PS 600/C/2 (Partner Corporation, Bucharest, Romania) with a precision of 0.001 g and data were recorded in a table for each sample. Minimally invasive access cavities were then realized for each tooth on the corresponding coronal surface (lingual or occlusal) under a dental operating microscope Alltion (Alltion, Wuzhou, China), at a magnification of 0.6x, using high-speed diamond burs under cooling water. Straight-line access to each root canal was verified with hand stainless steel K-files #10 (Kendo, VDW GmbH, Munich, Germany) and the access cavities were considered finished when respecting this requirement. Weights were measured again after access cavities; data were recorded in a Microsoft Excel table and compared with the initial ones. The loss of tooth structure was calculated as a difference between the initial and the final value (Table 1).

All root canals were shaped using the WaveOne Gold Primary 25/.07 instrument from the WaveOne Gold system (Dentsply Sirona, Ballaigues, Switzerland) fixed in the contra-angle piece of the X-Smart Plus endodontic motor (Dentsply Sirona) with the corresponding reciprocating setting of the motor, under constant irrigation with sodium hypochlorite NaOCl 5,25% (Chloraxid, Cerkamed, Stalowa Wolla, Poland) in alternation with citric acid solution 40% (Cerkamed). Initial negotiation with stainless steel hand K-files ISO 010 (Kendo, VDW GmbH, Munich, Germany) was performed to establish the working length. The irrigant was removed after shaping from each root canal using microcanulas for suction (Aplikatory, Cerkamed) connected to the surgical suction of the dental unit, dried with absorbent paper points (WaveOne Gold size Primary, Dentsply Sirona) and air from the dental unit, and each sample was weighted again. Measured values (g) were recorded and the tooth substance loss (g) was calculated again after the final shaping (Table 1). In total, each sample was digitally weighted three times: initial, after the access cavity preparation and after complete root canal shaping. Teeth fixed in the same vertical position were radiographically evaluated on another CBCT to observe the precision of the endodontic treatment and then digitally re-scanned on the corresponding coronal surface of the access cavity for each group.

Scanning analysis

The .STL (standard tessellation language) files before access cavities and after complete endodontic therapy were comparatively evaluated using the dedicated Planmeca Romexis software, to measure the loss of areas and volumes (Figures 1-3).

Figure 1

Initial aspect of samples 1-5 from Group 1 (Molars) digitally scanned (occlusal view) before the access cavity

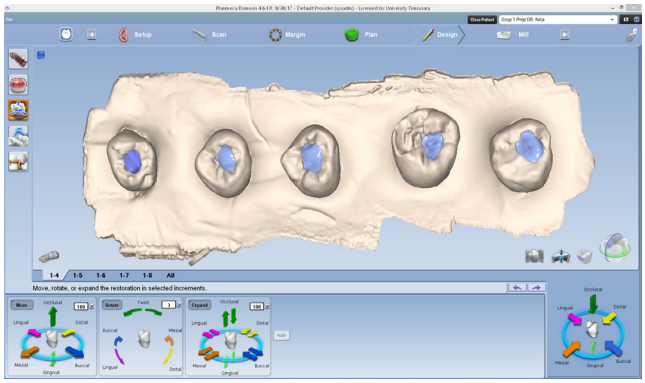

Figure 2.

Print screen of the Planmeca Romexis program with the occlusal surfaces of Group 1 after access cavities

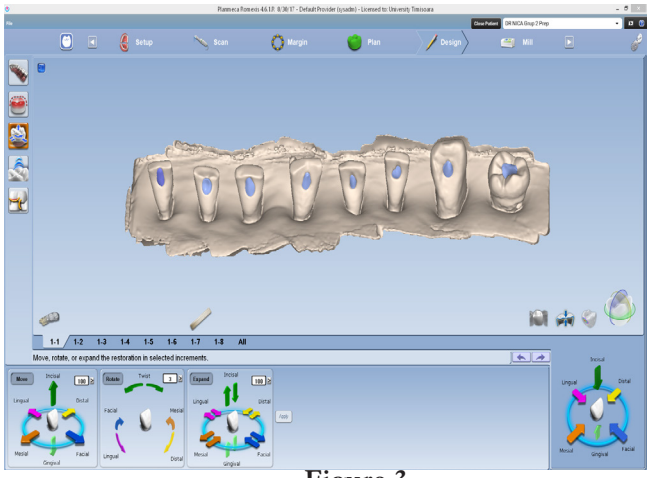

Figure 3

Digital model of the lingual access cavities for the incisors Group

RESULTS

Comparative results after weight analysis

The loss of tooth substance after access cavity preparation varied between 0.00 and 0.19 g in all teeth, with most of the teeth (11 from 18 samples) loosing between 0.00 and 0.05 g. For Group 1, molars, in 4 of the samples the difference varied between 0.01 and 0.05 g. Differences over 0.10 g (0.12, 0.13 and 0.19 g) were recorded in 3 of the 7 molars. In 5 from 8 samples of the incisors Group 2, no loss of tooth substance was recorded after the access cavity when the weight was registered only with hundredths of grams. For the premolars Group 3, the tooth loss varied between 0.03 and 0.04 grams (Figure 4).

The loss of tooth substance after shaping varied between 0.008 and 0.052 g. In Group 1, the variation was between 0.017 and 0.052 g, in Group 2 between 0.008 and 0.032 g, and for Group 3 a tooth loss between 0.010 and 0.038 g was recorded (Table 1).

The total loss after access cavity and shaping (total weight loss) varied between 0.017 and 0.213 g with the highest values recorded for the molars (0.036-0.213g), with a mean of 0.114 g, and the lowest for the incisors (between 0.012-0.028g, mean of 0.029g).

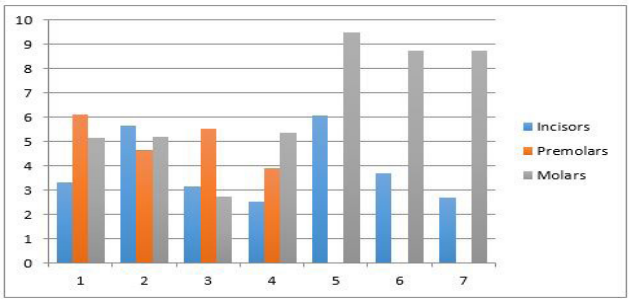

Figure 4

Weight variation (hundredths of grams) after access cavity in all three groups

Value	Weight loss after access cavity (g)	Weight loss after cleaning-shaping (g)	Total weight loss after endodontic treatment (g)
Min	0.010	0.017	0.036
Max	0.190	0.052	0.213
Mean	**0.077**	**0.033**	**0.114**
Min	0.000	0.008	0.012
Max	0.050	0.038	0.088
Mean	**0.010**	**0.017**	**0.029**
Min	0.030	0.010	0.040
Max	0.040	0.028	0.058
Mean	0.0325	0.017	0.049

Table 1.

Minimum, Maximum and Mean weight values (g) of tooth substance loss for Groups 1, 2 and 3 after each endodontic procedure

The premolars group recorded a mean total weight loss of 0.049g (Figure 5).

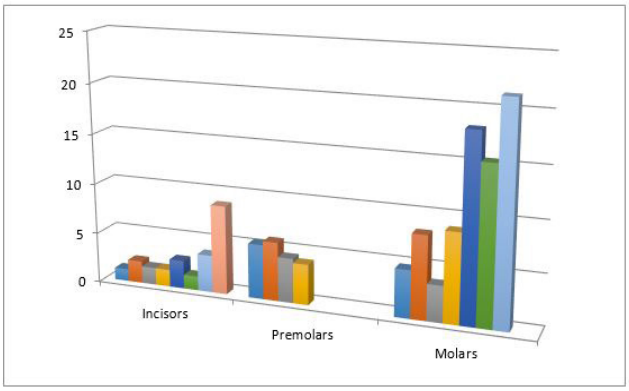

Figure 5.

Total weight loss variation (hundredths of grams)

In percentages, from the initial weight, the total weight loss varied between 2.53%, being the lowest value recorded in incisors (Group 2), with a mean of 3.86%, and 9.48%, recorded in molars (Group 1), with a mean of 6.48%. For Group 3, the percentages varied between 3.92 and 6.13, with a mean of 5.06 (Table 2). As observed, the highest amount of total tooth structure loss was lower than 10% from the initial weight.

Percentage of weight loss (%)	Incisors	Premolars	Molars
Min	2.53	3.92	2.75
Max	6.08	6.13	9.48
Mean	3.86	5.06	6.48

Table 2.
Percentage of tooth substance loss at the end of the endodontic treatment

Comparative results after digital scanning analysis

Area and volume loss after access cavities

On the scanned images, using the Planmeca Romexis Software, areas and volumes of tooth substance loss were calculated. For molars, the lost area varied between 11.5 and 23 mm2, with a mean of 15.92 mm2. Highest value was recorded in one molar, 23 mm2 (Figures 6-7).

For the premolars group, the values for area lost varied between 8.5 and 10.5 mm2, with a mean of 9.5 mm2. The highest registered value, 10.5 mm2, was bigger than in the incisors group, but lower than in molars, as expected.

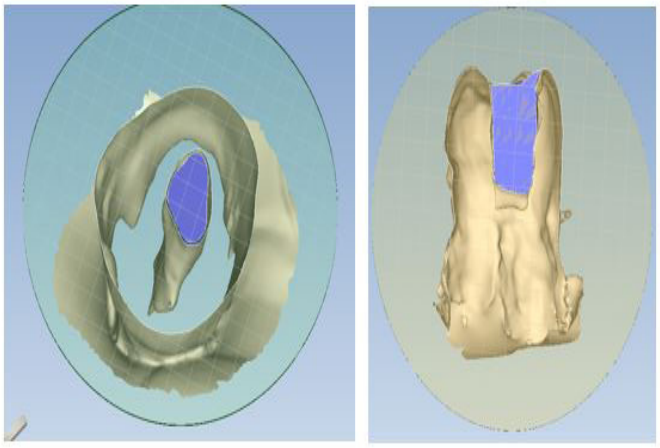

Figure 6 a,b.
Detail aspects inside the access cavities used for calculating the Lost Area and Volumes (Group 1)

The lowest values of lost area were registered for the incisors group, varying from 3 to 4.5 mm2, with a mean of 3.785 mm2.

As for the volumes loss, the lowest values were registered in incisors, and the highest in the molars group (Figure 8).

DISCUSSION

The comparative results registered for all 3 groups regarding area and volume loss are to be expected, taking into consideration the anatomy of each group type.

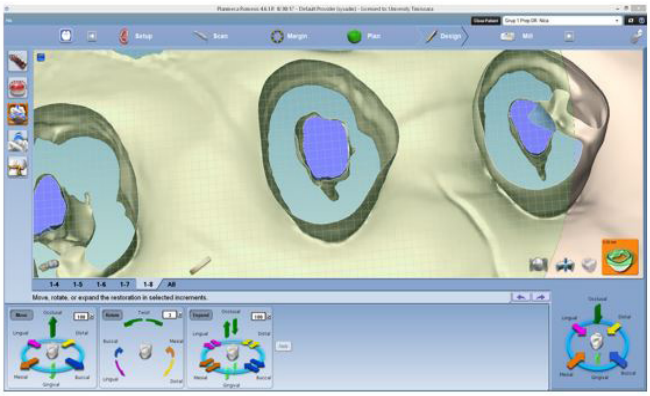

Figure 7.
Detailed print screen with the area measurements using the digital scale of the program

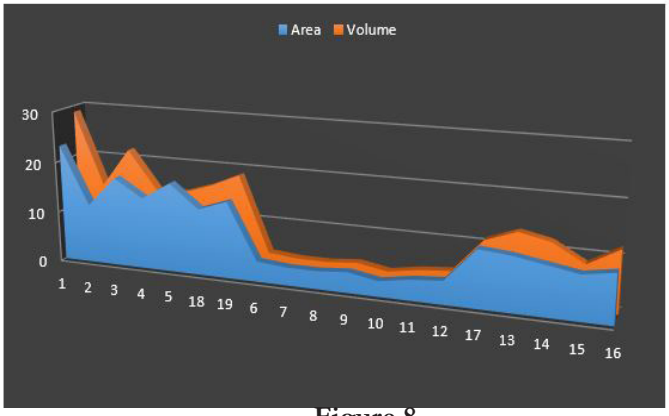

Figure 8
Area (mm2) and volume (mm3) loss after access cavities (Molars-samples 1-5, 18,19; Incisors-samples 6-12, 17; Premolars-samples 13-16)

The access cavity being totally depending on the size of the pulp chamber and the number of the root canals [23], with the smallest on the incisors (Group2) and the largest on molars (Group1), the highest sacrifice of tooth substance was recorded after performing access cavities on molars. Taking into consideration that all cavities were conservative prepared, as literature advices [24, 25], it is explainable why on lower incisors, with a small lingual tooth surface, the removal of tooth substance and the area loss registered the lowest values. Moreover, creating the access cavity minimally invasive under the dental operating microscope, the quantity of tooth substance removed was minimal and as a consequence not registered as weight loss in some of the incisors, even when the weight was recorded on a digital scale with a precision of 0.001 g.

Same results were observed for areas and volumes loss. The reduced size of the enamel and dentin layer upon the pulp chamber which was removed at the creation of the access cavities, of 1 mm thick in these teeth, and the minimally invasive design of the access cavities, determined the lowest values recorded in area and volume loss for the incisors group. These features will prevent the tooth fracture after endodontic treatment and will increase their resistance [25, 26]. Only in one central upper incisor, the quantity (g) and area (mm2) of the tooth substance loss was similar to the premolars group, explainable by the largest coronal

surface of this tooth and the bigger access cavity than in lower incisors.

The access cavity in premolars registered a higher loss of volume and area and the percentage of total loss from the initial measured weight was bigger than in incisors, as expected, but lower than in molars, in accordance to the total area of the occlusal surface comparative to the lingual access surface of the incisors.

The highest loss of tooth substance recorded in molars was normal taking into account the larger access cavity needed for the opening of the pulps chamber in order to find and shape all root canals. Also, the thicker enamel layer and dentin upon the pulp chamber in comparison with that in incisors group, measured on digital scans of 1.25 mm height, determined these results.

The CBCT analysis performed before any endodontic procedure presented the advantage of a more accurate location of the pulp chamber, thus allowing creating the access cavities with a minimum sacrifice of tooth substance, by locating the exact point of penetration and the possibility of the minimal extension of these cavities [21]. The preparation of all root canals with a system with decreasing taper from apical to coronal, like WaveOne Gold (Dentsply), limited the amount of tooth substance removed during the shaping procedure.

Although the phase of access cavity creation is the one with the main removal of tooth substance during an endodontic treatment, as quantity and as a percentage of total, when conservative design is used to create it under the dental operating microscope, variations of tooth substance loss can be minimal or even null when recorded in hundredths of grams, especially in lower incisors.

CONCLUSIONS

Both methods used in the present study proved that even for molars, the removal of tooth substance when creating minimally invasive access cavities is reduced, especially when working under magnification with the help of the dental operating microscope. Being much more conservative than traditional access cavities, the highest value of tooth substance loss recorded in the present study was hundredths of grams.

During root canal shaping procedure, a minimal amount of tooth substance as weight is removed (thousandths of grams).

Future studies including a larger number of teeth are necessary to evaluate the influence of these types of access cavities on the future fracture resistance of endodontically treated teeth.

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