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Porosities in dental restorative materials indicated for class-V cavities – a micro computed tomography based analysis.

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Acknowledgements

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Abstract

Background: Class-V fillings are thought as a demanding type of dental restorations having a sufficient risk of falling out and discoloration during follow-up. Porosity, among other factors, is described in the literature as an undesirable property of dental materials contributing to the development of secondary caries and reduction of the filling strength.

Objectivities: To evaluate a percentage amount of porosity in 5 restorative materials indicated to Class-V fillings.

Material and methods: fifteen human extracted wisdom teeth were sectioned into 4 parts and prepared standard class-V cavities restored with five different restorative materials (GC Fuji IX GP® EXTRA Japan, GC Fuji II LC® Japan, Ceram.x® Dentsply Sirona Germany, Tetric EvoFlow Ivoclar Vivadent Lichtenstein, SDR® flow+Bulk Densply Sirona Germany). The porosity of Class-V restorations was tested using micro computed tomography (SkyScan 1272 Bruker, Germany).

The detected porosities were calculated and analysed as a percentage value of total, closed and open porosity. The Anova on ranks test with Turkey post-hoc test was done to compare the differences in the median values among materials. A t-test or a Mann-Whitney Rank sum test were performed after a Shapiro-Wilk normality test to compare total, open and closed porosities within material groups.

The results: Significant difference was detected in each group when comparing glass-ionomers (Fuji Extra, Fuji IX) with resin-based composites (Ceram X, Tetric EvoFlow, SDR) in respect to total and closed porosity. When assessing open porosity, the significant difference was found between Fuji Extra and resin-based composites (Ceram X, Tetric EvoFlow, SDR) as well as between Fuji LC and Tetric EvoFlow.

Conclusion: This project reveals that in spite of the distinctive amount of porosity detected for each type of material, the significant difference is presented only between the representatives of the group of glass ionomer and composite.

Keywords

Porosity, voids, glass-ionomer, Micro-CT, bulk-flow, class-V restoration, non-carious lesion.

1. Introduction

1.1 Background

According to Black's classification of cavities, class-V is a cavity that is located in a gingival third of a labial, buccal, lingual or palatinal surfaces of any tooth (1). Class-V restorations on a cervical aspect of a tooth are placed either due to carious or non-carious lesions (2). It has been highlighted that a cervical placement of filling demands extra measures in regards to gingival health and pulp protection (3).

Formation of a carious lesion is mainly attributable to the influence of carbohydrate-modified bacteria which contribute to the decrease of cariogenic potential (4). The term of a non-carious cervical lesion (NCCL) is based on a loss of dental tissue due to factors described in the literature as abrasion, attrition, erosion and abfraction (5). However, identifying the specific aetiology of NCCL is complicated due to the many factors responsible for such lesions (6).

A clinical study conducted in 2012 revealed that NCCL is a condition that appear in two variations i.e. wedge-shaped and saucer-shaped lesion. Moreover, development of each variance depends on the influence of differing contributing factors (7).

The prevalence of NCCL varies from study to study; however, it strongly correlates with the age of participants. For instance, young males aged 31 and adult males at the age of 60 years represented prevalence of 2% and 85%, respectively (8, 9).

In a clinical study conducted in 2010, it was revealed that caries lesion and non-caries lesion were registered in 32.7% and 67.3% respectively, among 1000 of cavities with class -V configuration (10). Clinically, NCCL manifest as a tooth hypersensitivity caused by a motion of fluid in open dentin tubules (11). Such exposed dentine gives a wide range of response from a short-lasted sensitivity to a severe form of a painful condition that strongly affects the quality of life (12).

The necessity to treat depends on the chief complains and, in some cases, the strategy of "wait and watch" can be applied as an option (13, 14). Another approach suggests pursuing active treatment, relying on the fact that NCCL are associated with the plaque accumulation and the subsequent progression of periodontitis and caries (15).

The management of NCCL is considered as one of the most challenging restorative treatment, which is often associated with a high rate of retention loss, marginal discoloration and secondary caries (16). Meta-analysis including fifty clinical studies revealed in 2010 that on average, 10% of cervical restorations were lost and 24% had signs of marginal discoloration after 3 years of function. The result was significantly influenced by the type of adhesive system and dentin preparation prior to restorative procedure (17).

The low success rate of class-V restorations can be explained by inadequate moisture control, adhesion to hard dental tissue (enamel, dentine and cementum), differences in dentin composition as well as cusp movement during occlusion (13).

Certain types of restorative materials are indicated for class-5 cavities: Glass ionomer cements (GICs), Resin-modified GICs (RMGICs), Liner base laminated with a resin composite a GIC/RMGIC, and Resin composite in combination with a dentine bonding agent (13). The restorative materials for class-V restorations accepted in the university dental clinic in Tromsø reflect these findings. Such, the group of glass ionomer cement (GICs) is represented by GC Fuji IX GP® EXTRA. GC Fuji II LC® represents the group of resin-modified GICS (RMGICs). Ceram.x® Dentsply Sirona is a conventional resin composite used in combination with bonding agent. Tetric EvoFlow, Ivoclar Vivadent belongs as well to resin composite restorative material and has a flowable consistence. SDR® flow+ Densply Sirona is a bulk-fill resin composite material.

Nowadays, there is no consensus in the literature regarding the range of restorative materials performing the best and the worst quality. The systematic review conducted in 2014 concluded that a glass-ionomer cement has a significantly lower risk of restoration loss comparing to adhesive technique (18). A similar result was detected in another systematic review in 2014 where the result was measured by annual failure rate (AFR) score. The authors defined that a glass-ionomer restoration had the lowest AFR score as compared to adhesive technics (19). However, in contrast to these 2 studies, the meta-analyse conducted in 2010 found out that 2-step self-etching and 3-step etch&rinse systems shall be prioritized over glass-ionomer and 1-step self-etching system in terms of retention loss and marginal discoloration (17). In addition to the lack of research consensus in respect to the most optimal material, there is no definitive consensus as well between practical dentists regarding the choice of restorative materials applied to cervical fillings (20).

Entrapment of air inside the material is a disadvantage of restorative technique leading to the formation of voids and bubbles with a following deterioration of the mechanical properties of resin composites, especially under fatigue loading (21, 22). Voids situated on the restoration margin may cause gross microleakage and discoloration (23). In contrast to narrow gaps, ditches and microleakage, the voids are deemed as a contributively factor for the development of secondary caries (26). The volume of voids or porosity is also a subject of physic-mechanical characteristics of restorative material. Particularly, Nomoto et al. in 2004 revealed that a porosity of 0.2% causes 10% reduction in strength of glass-ionomer restorative cement (24).

There are several methods established to evaluate microleakage between tooth and restorative material, such as: dye penetration, electromecanical method, radioisotope labelling, fluid filtration and analysis by electron microscopy (25). Among all, the dye penetration is the most used in the researches because of its simplicity and sensitivity (25, 26). However, this method has as well its disadvantages due to a subjective evaluation and a necessity to destructive sectioning of experimental teeth. These facts promoted a development of more advanced 3D micro-computed tomography (micro-CT) technology giving three-dimensional image without tooth sectioning (27, 28). An in-vitro study conducted in 2015 revealed no significant differences between micro-CT and low-resolution scanning electron microscopy estimating the results of sealing ability in class-V restorations. The authors suggested that micro-CT is a reliable and non-destructive method for quantitative evaluation of marginal leakage (29). Another in-vitro study conducted in 2016, concluded that micro-CT is not yet vulnerable method of class-V microleakage estimation because of the result of micro-CT and stereomicroscopy was contrary different. (30)

1.2 The purpose of the study

A deep insight into background information related to the use of micro-CT for the testing of class-V fillings has led us to the idea that the topic is not yet fully disclosed. Studies conducted earlier suggested micro-CT scanning of the tooth as a whole that potentially may decrease a resolution of CT image. We assumed that the high-quality micro-CT image can be taken if the object of interest will be maximally approached and adapted to the border of CT focal space. For this purpose, it has been suggested to perform sectioning of experimental teeth in the way giving surfaces suitable for class-V and fill them afterward. Obtained CT image has resolution that makes possible to apply software for calculation of the value of porosity between different restorative materials indicated for class-V cavity.

1.3 Research questions

The main research question was:

Is there a difference in the total, open and closed porosities in five restorative materials indicated for class-V cavity restoration?

1.4 The hypothesis

It was hypothesized a priori that the five restorative materials (GC Fuji IX GP® EXTRA, GC Fuji II LC®, Ceram.x® Dentsply Sirona, Tetric EvoFlow Ivoclar Vivadent, SDR® flow+Bulk Densply Sirona) would yield the same level of porosities assessed by Micro-CT.

2. Materials and Methods

2.1 Samples

Type of samples

We have used human teeth, which were extracted under medical indications, for instance, wisdom tooth retention, complicated periodontitis or pre-orthodontic extraction. The request about a gathering of the targeted teeth was sent to the all public dental clinic in Tromsø, UTK and surgical department of TKNN, Tromsø (Table 1). During the period from 08.2017 to 10.2017, the necessary amount of tooth was collected. In order to gain a maximal compatibility of the samples, it has been set a several inclusion criteria for the collected teeth:

1. Extracted teeth should be immediately immersed in the distillate water and further preserved in a fridge under temperature (4±1) C., according to ISO/FDIS29022:2012(E)
2. Teeth should have not exposed enamel-cementum junction with no sign of caries or previous restorations, no visual micro fractures or other defects caused by extraction.
3. Teeth should be delivered to the UTK laboratory once they are extracted.

It has been collected 78 teeth but 63 teeth were excluded because of not meeting the inclusion criteria. As a result, 15 teeth were included into further procedures (Table 1). This group was represented by third molars extracted from both jaws.

Table 1. An overview of the participated clinics and a number of included teeth.

Clinics	Number of collected teeth	Number of teeth which met inclusion criteria	Exclusion reason
Kroken dental clinic	62	0	Long-lasted storage in alcohol
Nørdøya dental clinic	4	4	-
UTK student dental clinic	1	1	-
TKNN, surgical department of UTK	11	10	caries
Total	78	15	

In vitro assessment

For the purpose of this study, it has been suggested to conduct all restorative procedures outside of human mouth cavity. Separation, preparation and fillings placement were done in the student dental clinic in order to mimic real treatment conditions as much as possible.

Ethical consideration

Since human teeth were used in this study, it was necessary to apply for obtaining an ethical permission from the Regional committees for medical and health research ethics (REK). REK made a conclusion that this study was not a subject of health research legislation; therefore, the permission was not needed (See appendix 1). All information about samples was anonymised, samples were collected without any marks or references to the personal data. Teeth were stored in the UTK laboratory in the common glassware; the sequence of the teeth preparation was random.

2.2. Clinical procedures

Sample preparation

For the purpose of this study, "sample" was defined as a part of tooth suitable for the in-vitro placement of the restorations equivalent to class-V cavity. The teeth were sectioned prior to the restoration to avoid any potential distortions to the restoration, which can be caused by the abrasive instruments (separation disc for exp.). Each tooth has four relevant surfaces for the obtaining of sample, such as: buccal, lingual, mesial and distal wall of enamel-cementum junction. Teeth were separated in the following technic:

- The first section separated the root from the crown 2 mm down from the cement-enamel junction;
- The second one separated the upper part of the crown from the crown body 2 mm up from the cement-enamel junction;
- The obtained puck-like form sample divided further into 4 equal parts by two cross-sections going through the centre. (See appendix 2).

Consequently, it was obtained 60 samples after teeth dissection, however not all were included in the further procedures. The width and height of the samples varied because of the different anatomy and size of the teeth. Ten out of sixty samples had a vertical size less than 3 mm, hence, they were excluded from the further analysis. Particularly the size – 3mm has been deemed as an optimal taking into consideration that the diameter of filling is 2.3 mm and the surrounded enamel around the filling borders is needed. Vertical dimension of the samples was measured by the use of callipers (See appendix 3).

Further procedures included preparation of identical cavities class-5 in each of the 50 samples. Identical cavities were achieved by using the same set of diamond burs. The preparation begun with a penetration of the enamel by a diamond bur with diameter 2.3 mm (GEBR. BRASSELER GmbH & Co. KG, Germany) a final formation of the cavities was achieved by the sinking the half of the bur with a diameter 2.7mm (GEBR. BRASSELER GmbH & Co. KG, Germany). This technique gave a saucer-like form of a cavity with an approximate size 2.7/1.35 mm and provided a butt-joint connection between fillings and tooth substance. A yellow polishing cone (TopDent Composite polisher Y-2, DAB Dental, Sweden) was used for eventual removing of excessive parts of filling and final polishing.

Restorative materials

Restoration of class-V cavities was listed as an indication for use in Instruction for Use of all the investigated materials: GC Fuji IX GP® EXTRA Japan, GC Fuji II LC® Japan, Ceram.x® Dentsply Sirona Germany, Tetric EvoFlow Lichtenstein, Ivoclar Vivadent, SDR® flow+Bulk Densply Sirona Germany hence, have been chosen for the test.

Each material represented different brand and type (Table 2). Bonding, etching and filling techniques were chosen in accordance with manufacturer recommendations and clinical guidelines accepted at UTK in respect to management of class-V cavities. In accordance to manufacturer guidelines, glass ionomer containing fillings (GC Fuji IX GP® and GC Fuji II LC®) were covered by nanofilled self-adhesive light-cured coating GC G-Coat Plus, Japan.

Table 2 Types of restorative materials.

Brand (manufacturer)	Type	Etching	Bond	Filling technique	Coating
Tetric EvoFlow, (Ivoclar Vivadent)	flowable composite	Ultra Etch - 35% phosphoric acid	Clearfil, 2-steps, primer + bond	One portion	No
SDR® flow+ (Densply)	bulk fill	Ultra Etch - 35% phosphoric acid	Clearfil, 2-steps, primer + bond	One portion	No
ceram.x®, (Densply)	conventional composite	Ultra Etch - 35% phosphoric acid	Clearfil, 2-steps, primer + bond	Incremental technic, 2-3 layers.	No
Fuji II LC® CAPSULE (GC)	light curing glass ionomer	Conditioner – 20% polyacrylic acid	-	One portion	Yes
Fuji IX GP Extra Capsule Refills (GC)	chemical curing glass ionomer	Conditioner – 20% polyacrylic acid	-	One portion	Yes

2.3 Laboratory procedures

Once the placement of the restoration was done in the student dental clinic, all 50 samples were immersed into glass with distillate water, marked and delivered to the dental material testing laboratory IKO UIT, Tromsø.

Micro-CT

The laboratory IKO, UIT is equipped by the micro-CT Sky-Scan 1272 Bruker, Germany which is constructed for medical researches where a high resolution is needed.

The Sky-Scan 1272 had the following technical settings for the scanning of samples:

- Voltage: 100 kV
- Filter: Cu 0.11mm
- Rotation step: 0.4°
- 360° rotation around the vertical axis
- Frame averaging: 4
- Resolution: 8µm
- Camera exposure time: 3500ms

These properties allowed gaining spatial x-ray picture with a resolution suitable for the identification of the porosities outside and inside the object.

The images were reconstructed using the software Nrecon (Version 1.7.1.0, Skyscan, Belgium). The adjustment of the reconstruction parameters allowed to suppress noises, set ring artefact correction values, beam hardening correction postalignement and adjust dynamic image range.

The resulting images were analysed with the software CTAn (Version 1.16.4.1, Skyscan, Belgium) and morphometric results were calculated.

Output

The Sky-Scan 1272 has the software that compatible with the Microsoft Excel. The output of 50 x-ray tests was transferred and performed in the separate 50 Microsoft Excel files. Information about each sample comprised of more than 100 characteristics of the object. Among them open porosity, closed porosity, and total porosity were the parameters of interest. A value of these 3 parameters was extracted from all 50 files and included in the newly created Excel file. This file was transferred further to the statistic program – Sigmaplot 13.

Statistics

Microsoft Excel was used to obtain a bar graph showing percentage differences among 5 groups of restorative materials relating to a presence of porosities.

Graphing and statistical analysis were conducted in Sigmaplot 13 (Systat. Software, San Jose, CA, USA). For the descriptive statistics, all results are presented as the mean value of ten samples for each group with standard deviation (indicated by ±). A One-Way analysis of Variance on ranks (Kruskal-Wallis) with an alpha value of 0.005 were used to compare the amount of porosities between groups. A t-test or a Mann-Whithney Rank sum test were performed after a shapiro-Wilk normality test to compare total, open and closed porosities within material groups.

3. Result

3.1 Descriptive statistic

Since the data was not normally distributed, Table 3 was created to give an overview of mean, median, standard deviation as well as minimal and maximal value of variables.

Table 3. Distribution of mean, median, SD, min and max value.

	Mean	Median	Standard deviation	Min	Max
	Total porosity (%)				
SDR® flow+ Densply	1.10	0.85	0.82	0.60	3.37
Tetric EvoFlow, Ivoclar Vivadent	0.61	0.60	0.21	0.30	1.12
Fuji IX GP Extra Capsule Refills GC	6.51	6.08	1.57	4.56	9.35
Fuji II LC® CAPSULE GC	5.27	5.46	1.11	3.84	7.33
Ceram.x®, Densply	1.05	0.91	0.64	0.44	2.69
	Open porosity (%)				
SDR® flow+ Densply	0.94	0.71	0.78	0.43	3.06
Tetric EvoFlow, Ivoclar Vivadent	0.41	0.39	0.12	0.24	0.67
Fuji IX GP Extra Capsule Refills GC	3.17	2.96	1.38	1.79	6.73
Fuji II LC® CAPSULE GC	1.81	1.65	0.81	0.90	3.72
Ceram.x®, Densply	0.84	0.64	0.66	0.40	2.62
	Closed porosity (%)				
SDR® flow+ Densply	0.16	0.16	0.07	0.04	0.31
Tetric EvoFlow, Ivoclar Vivadent	0.20	0.13	0.22	0.06	0.82
Fuji IX GP Extra Capsule Refills GC	3.44	3.41	0.95	1.40	4.83
Fuji II LC® CAPSULE GC	3.52	3.40	0.70	2.80	4.91
Ceram.x®, Densply	0.21	0.26	0.13	0.03	0.41

3.2 Comparison of groups

The chemically cured material Fuji IX GP Extra had the highest percentage mean value in respect to total and open porosities, 6.51 % and 3.18% respectively (Fig.1) The highest mean value of closed porosity was detected in the group of Fuji LC – 3.52%. Tetric EvoFlow had the lowest percentage mean value measured by the presence of total and open porosity, 0.61% and 0.41% respectively. The lowest mean value of closed porosity was observed in the group of SDR (0.16%). In general, composite materials had lower amount of porosities as compared to glass ionomer materials

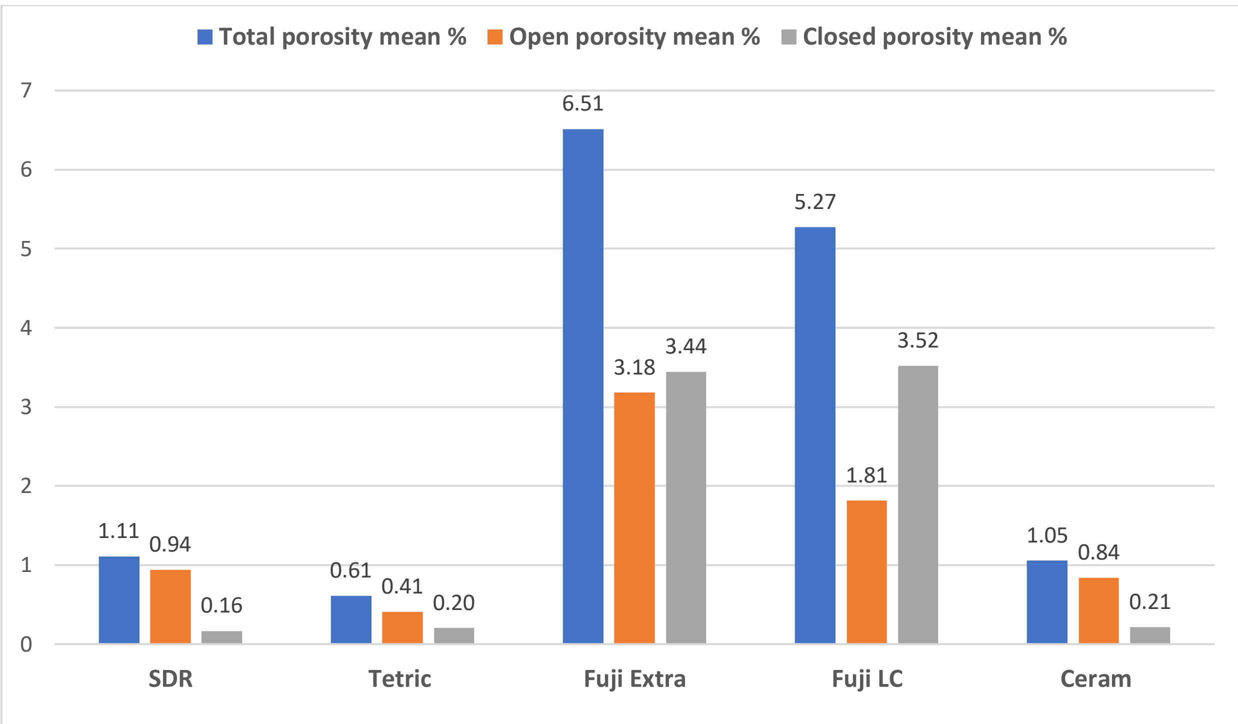

Figure 1. Comparison of mean value of 10 samples estimated in % among 5 types of restorative materials**.**

3.3 Proportion between open and closed porosity within total porosity

The lowest and the highest percentage of closed porosity were detected in the group of SDR and Fuji LC, 15% and 66%, respectively (Fig. 2). The highest and the lowest value were detected for open porosity in the same groups but with inversely relation – SDR-85% and Fuji LC-34%, respectively.

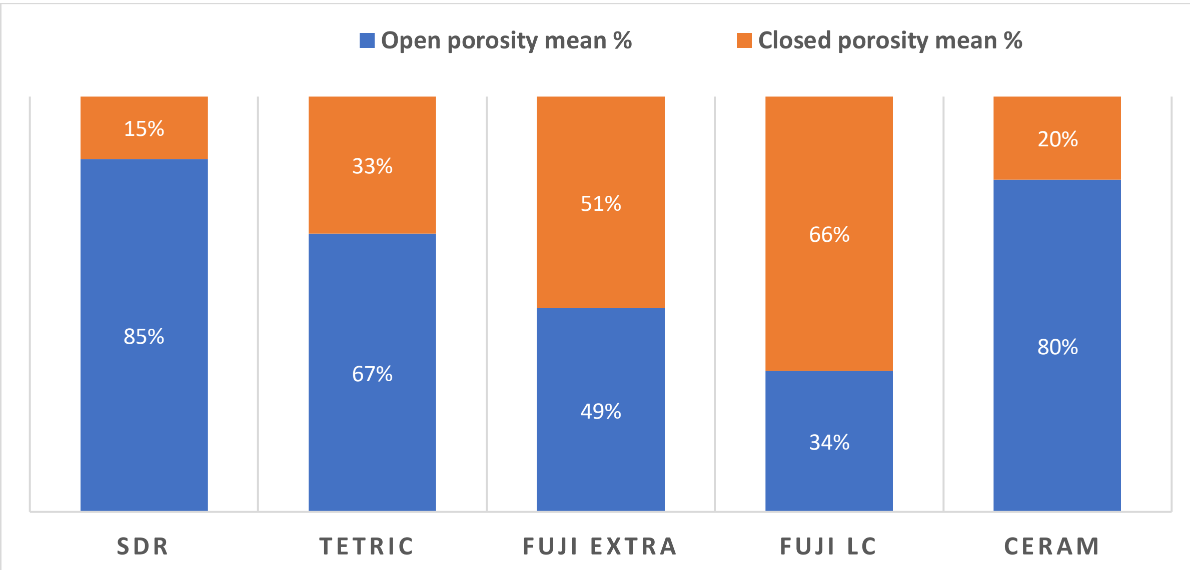

Figure 2. Percentage proportion of open and closed porosities combined as 100% value of total porosities. According to t-test or a Mann-Whitney Rank test, all the materials except Fuji Extra had a significant difference comparing open and closed porosities within material groups ($p<0.05$)

3.4 A range between minimal and maximal outliers

According to Kruskal-Wallis test, there was a statistically significant difference between all five materials ($p<0.001$) regarding total, open and closed porosity. Figure 3,4,5 represent a median value and a difference between the minimum and maximum value of porosity detected based on the analysis of 10 samples for 5 restorative material. The narrowest range between samples was detected for Tetric EvoFlow when analysing total and open porosities; SDR has the same characteristic in the group of closed porosities (Fig.3-5). The widest range between minimal and maximal outliers was revealed for Fuji Extra in all 3 groups of total, closed and open porosities (Fig. 3-5).

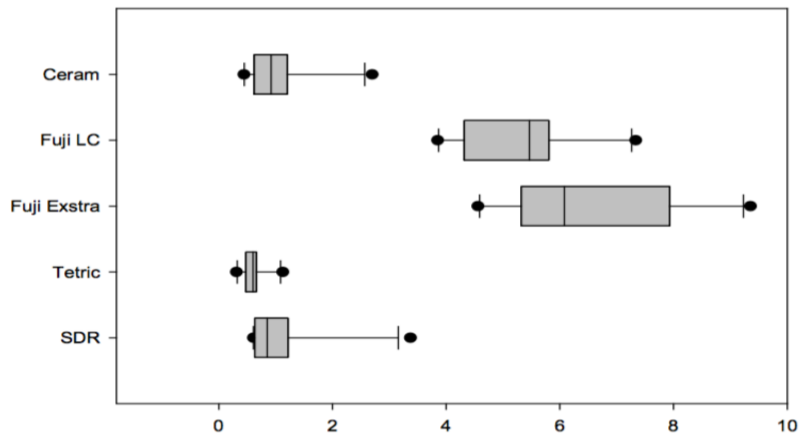

Figure 3. Box plots of data on total porosities from the five restorative materials

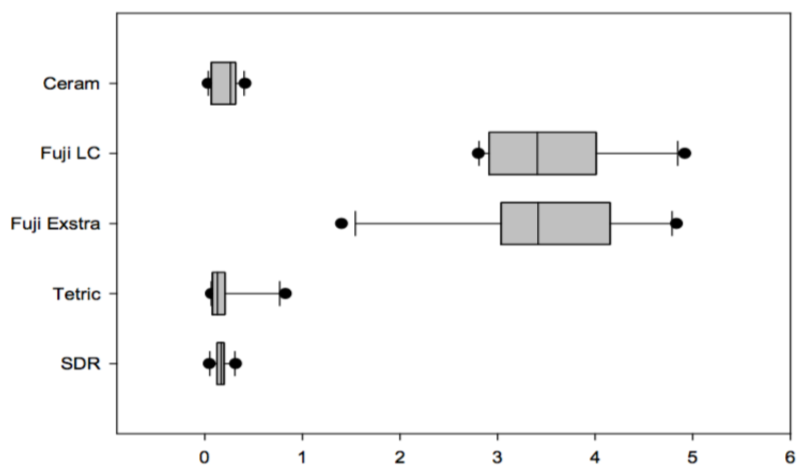

Figure 4. Box plots of data on open porosities from the five restorative materials

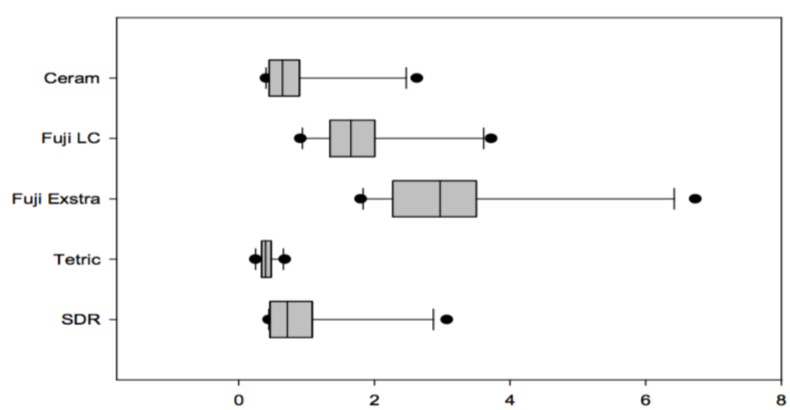

Figure 5. Box plots of data on closed porosities from the five restorative materials

3.5 Statistical comparison of the groups

Pairwise multiply comparison test revealed that Fuji Extra and Tetric EvoFlow, Fuji Extra and Ceram X, Fuji LC and Tetric EvoFlow, Fuji LC and Ceram X, Fuji LC and SDR were statistically significantly different when comparing total porosity and closed porosities (Fig.4) Statistically significant difference between Fuji Extra and Tetric EvoFlow, Fuji Extra and Ceram X, Fuji Extra and SDR, Fuji LC and Tetric was detected when comparing open porosities (Fig.4).

Table 4. Pairwise multiply comparison, according to Anova on ranks and Turkey post-hoc tests.

	Total porosity			Open porosity			Closed porosity		
Comparison	q *	p	P< 0.05	q *	p	P<0.05	q *	p	P<0.05
Fuji Extra / Tetric	7.332	0.001	Yes	7.614	0.001	Yes	5.944	0.001	Yes
Fuji Extra / Ceram X	5.358	0.001	Yes	5.076	0.003	Yes	5.033	0.003	Yes
Fuji Extra / SDR	5.141	0.003	Yes	4.707	0.008	Yes	5.553	0.001	Yes
Fuji Extra / Fuji LC	1.041	0.948	No	1.801	0.708	No	0.174	1.000	No
Fuji LC / Tetric	6.291	0.001	Yes	5.814	0.001	Yes	5.770	0.001	Yes
Fuji LC / Ceram X	4.317	0.019	Yes	3.276	0.140	No	4.589	0.005	Yes
Fuji LC / SDR	4.100	0.031	Yes	2.907	0.240	No	5.380	0.001	Yes
SDR / Tetric	2.191	0.530	No	2.907	0.240	No	0.390	0.999	No
SDR / Ceram X	0.217	1.000	No	0.369	0.999	No	0.521	0.996	No
Ceram X / Tetric	1.974	0.630	No	2.538	0.377	No	0.911	0.968	No

q - The studentised range distribution, shows a difference between the larges and the smallest data in sample.*

4. Discussion

In this Master Thesis, we used a term of porosity as a main definition describing an empty space located inside or on the surface of the restorative material. However, in the literature the same physical property is being discussed as well as voids and gaps. Hence, we accepted an equal meaning for these definitions in the discussion.

4 .1 Limitation of the study

As it has been mentioned in the study 2015, gaps were more associated with the effect of shrinkage and operator skills but voids were rather caused by disadvantages of the mechanical property of a material (31). In this Master project, we did not focus on the differences between gaps and voids but created the third variable of interest – porosity, combining all air inclusions detectable by Micro-CT.

The aetiology and localisation of porosity has a great interest for the fulfilment of preventive measures. The study conducted in 2009 defined that voids are tended to be more localised at the line-angles or cavity base with a size range from less than 1 μm up to several tens of micrometer (32). Assumable, the more peripheral localisation of voids is due to some specific factors. Indeed, it has been discussed several factors causing porosity (voids and gaps) in the restorative materials such as: cavity factors including number of walls, access and wall quality (33, 34); operator factor comprising type, handling and method of the insertion of the material (35-38). All these factors contributing to the formation of voids between cavity walls and restorative material (31).

We assumed that both cavity and operator factors would be worthy to investigate applying to the porosity in Class-V restorations because of micro-CT enables this kind of examination. But, due to a limit of time and capacity, this Master project was dedicated only to a percentage of porosity among different restorative materials without referring to the causal factors.

4.2. Micro-CT analysis

Novelty 1

The micro-CT method has been recently emerged as a popular tool of evaluation used in the field of dental biomaterials. Having an ability of 3D reconstruction, this method found a wide application for the evaluation of dentin-adhesive surfaces, microleakage and composite polymerisation shrinkage (28, 39, 40). A presence of micro voids is also subjected to the micro-

CT analysis referring to the fact that micro voids can lead to the damage formation (small defects and cracks) in dental composites (41). There are some controversial results found in respect to the use micro-CT for the detection of microleakage for class-V cavities. Such, the study conducted in 2016 revealed that micro-CT is not vulnerable method to evaluate marginal integrity. Interesting, that at the same time this study reported about a significant difference between the groups of adhesives estimating on the presence of voids (30). Another study launched in 2015 reported positively in respect to the use of micro-CT for the detection of microleakage for class-V cavities (29). In this Master Thesis, we assumed that such disagreement probably, can be due the result of non-perfection of parameters used currently for the micro-CT analyses. Indeed, the study dealing with the issue of micro-CT assessment of filling marginal integrity used different resolution parameters such as: 18 µm, 19.1 µm and 20 µm (29, 30, 42). At the same time, the article written in 2016 suggested that an increase of resolution is a one among other factors which can improve a defect detectability in composites conducted by X-ray micro tomography (41). Following this suggestion, we used a parameter of resolution - 8µm that provided the image with a quality allowing a quantitative voids calculation.

Novelty 2

One of the advantages of 3D analysis is a possibility to conduct a test in a non-destructive method, without separation of an experimental tooth (41). Non-destructive nature of analyse has been discussed as the advantage allowing to test the same sample many times (43). Separation of the samples was mentioned only once in the literature concerning to 3D analyses when the coronal part of a tooth was dissected from the root part (43).

The teeth used for this Master project were dissected to increase the size of object of interest and place it closer to the borders of CT focal space. Thus, we expected to gain an improved image quality. It is widely accepted to perform dissection of an experimental tooth after the placement of restoration (29, 42). We assumed that this approach can negatively effect on the integrity of a restoration in the cavity and distort the result of the micro-CT test because of the possible negative effect of abrasive instruments (separation disk for instance). In this project, a separation of experimental teeth was done before placement of filling and micro-CT analyses.

4.3 The difference of voids amount within different types of restorative materials.

Currently, there are scarce evidence regarding the porosity to class-V restorations assessed by micro-CT technique. Perhaps, it is due to that the micro-CT technique has not reached its limit in respect to the examination of the restorative materials. To comment the result of this Master project it was necessarily to analyse all types of evidence even if the study design was not directly related to what we did. Such, the study conducted in 2006 detected well-defined voids in 85-100% of samples of hybrid composite restorations assessed by electron microscope (44). That corresponds to our findings since all micro-CT scanners revealed a presence of porosity in all tested samples.

In 2016 the study examined difference in a percentage of voids between standard resin based hybrid composite and bulk-fill resin based composite (45). The experiment was performed on the posterior teeth restorations using micro-CT technique. The authors concluded that incrementally placed restorations and bulk-filled restorations had statistically significant difference percentage of porosity, 2.87% and 1.42%, respectively (45). In our study, it was also used Ceram X, a composite placed in incremental technique, and SDR, which belongs to the group of bulk-fill composites. We found the opposite result; Ceram X and SDR revealed an approximately identical mean of porosity 1.05% and 1.11%, respectively, which was not statistically significant.

A viscosity of the restorative materials is being speculated in the literature as a property contributing to the formation of voids. Such, the lowest number of internal voids were detected in the groups of low viscosity composites as compared to a group of high viscosity composites (31). Another study revealed in 2004 that a formation of gaps due to a polymerisation shrinkage is also correlated with high viscosity composites (46). These features can be explained by the fact that low viscosity materials have higher thixotropic effect and low polymerisation shrinkage due to their low elasticity modulus (47). The management of the material is also a matter of minimization of voids. It’s been highlighted that low viscosity material syringed into the bottom of cavity has less voids as compared to high viscosity materials (23). This can be explained by the potential formation of internal voids between layers in high viscosity materials (23). These evidences reflected partially our findings. The issue of material viscosity was not the aim of this Master project however, we used the material with different thixotropic property. According to instruction of a use, SDR and Tetric belong to the flowable composites and Ceram X is a conventional composite. We detected that among flowable composites only Tetric has lower percentage of voids as compared to Ceram.x, 0.61% and 1.05%, respectively. However, this difference was not statistically significant.

It has been thought that glass-ionomer types of cement have lower mechanical strength and lower wear resistance as compared to resin composites (48). This disadvantage can be explained by the microstructures and a presence of a high porosity (49, 50). The study conducted in 2015 assessed a percentage of porosity in total volume with the use of scanning electron microscopy, where the samples were resin-modified glass-ionomer, conventional glass-ionomer and nano-hybrid composite restorations, which had a percentage of porosity 5.69%, 7.54% and 1.21%, respectively (51). These findings correspond closely to our result. Such, we found that Fuji LC which belongs to resin-modified glass-ionomer had a total porosity 5.27%. Conventional glass-ionomer Fuji Extra contained 6.51% of total porosity in our study. However, the difference was not significant between these 2 types of glass-ionomer cements.

4.4 The disadvantages associated with voids formation.

Several factors have been discussed which can explain how a presence of porosity effects on restorations. Firstly, porosity reduces physical-mechanical properties of restorative materials. A reduction of strength on 10% and 50% was detected at the presence of 0.2% and 3% of porosity for glass-ionomer and luting cement, respectively (24). To our knowledge, there is a lack of a similar analysis in respect to the composite restorative materials. Secondly, formation of the gaps on the interface of restorations contributing to the development of postoperative sensitivity and microleakage (52, 53). As well as secondary caries at the walls between restoration and tooth which can appear in the presence of gaps. The study conducted in 2007 analysed a range of gaps from 25 μm to 1000 μm and suggested that the size of gaps affect a development of secondary caries (54).

5. Conclusions

The result of the current Master project shows that Micro-CT analysis is a reliable enough method to detect internal and external porosity in the restorative materials.

The presence of porosities was detected in all the restorative materials indicated for class V restorations. However, glass ionomers have more total, open and closed porosities than composite materials and bulk fillings. The clinical implication cannot be clear formulated in the form of guidelines due to the fact that there are many other factors, besides voids, which affect restoration quality. A presence of voids, in spite of its negative nature, does not presuppose a dramatic reduction of a restoration quality. However, a difference in voids percentage value should be taken into account for choosing the most optimal type of restorative materials for each separate clinical case.

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Appendix 1

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK nord	Veronica Sørensen	77620758	08.05.2017	2017/881/REK nord
			Deres dato:	Deres referanse:
			03.05.2017	

Vår referanse må oppgis ved alle henvendelser

Lina Stangvaltaite
TANN-bygget Hansine Hansensvei 86

2017/881 Tømmer i dental restaureringsmaterialer: sammenligning av mikro-CT.

Prosjektleder: Lina Stangvaltaite

Bakgrunn og formål (original):
This is a laboratory study using extracted human teeth. Around 30 extracted teeth will be collected from the oral surgery department at TkNN. The human teeth will be extracted due to medical reasons, which will not be the purpose of this study. Etracted teeth will be prepared and restored with four different dental materials. Using micro-CT the teeth will be scanned and the volume of voids in dental materials will be calculated and compared between different materials. .

Framleggingsplikt
De prosjektene som skal framlegges for REK er prosjekt som dreier seg om "medisinsk og helsefaglig forskning på mennesker, humant biologisk materiale eller helseopplysninger", jf. helseforskningsloven (h) § 2. "Medisinsk og helsefaglig forskning" er i h § 4 a) definert som "virksomhet som utføres med vitenskapelig metodikk for å skaffe til veie ny kunnskap om helse og sykdom". Det er altså formålet med studien som avgjør om et prosjekt skal anses som framleggelsespliktig for REK eller ikke.

I den vedlagte protokollen beskrives formålet som å sammenligne volumet av hulrom mellom fire forskjellige dentalstøttende materialer.

Man vil undersøke klasse 5-ikke-karisk hulrom i 30 tenner (som er trukket i forbindelse med ordinær tannlegebehandling)ved bruk av mikroberegnet tomografi.Nulhypotesen er at de fire forskjellige restaureringsmaterialene (Ceram - X, Tetricflow,Fuji - II LC, Vitremer) ville gi det samme volumet av hulrom som ble vurdert avMicro-CT.

Videre beskrives et at «Dette er en laboratorieundersøkelse ved hjelp av ekstraherte menneskelige tenner. Rundt 30 utvunnet tenner vil bli samlet inn fra Dental kirurgisk avdeling ved TkNN.

Tennene vil bli forberedt og restaurert med fire forskjellige tannlege materialer. Ved hjelp av mikro-CT blir tennene skannet og volumet av hulrom i dentalmateriale vil bli

Beregnet og sammenlignet mellom forskjellige materialer.

Slik formålet er beskrevet er det ikke egnet til å fremskaffe ny kunnskap om helse og sykdom slik dette er definert etter helseforskningsloven.

Prosjektet skal således ikke vurderes etter helseforskningsloven.

Besøksadresse:
MH-bygget UiT Norges arktiske universitet 9037 Tromsø

Telefon: 77646140
E-post: rek-nord@asp.uit.no
Web: http://helseforskning.etikkom.no/

All post og e-post som inngår i saksbehandlingen, bes adressert til REK nord og ikke til enkelte personer

Kindly address all mail and e-mails to the Regional Ethics Committee, REK nord, not to individual staff

Godkjenning fra andre
Det påhviler prosjektleder å undersøke hvilke eventuelle godkjenninger som er nødvendige fra eksempelvis personvernombudet ved den aktuelle institusjon eller Norsk senter for forskningsdata (NSD).

Etter søknaden fremstår prosjektet ikke som et medisinsk og helsefaglig forskningsprosjekt som faller innenfor helseforskningsloven. Prosjektet er ikke fremlegginspliktig, jf. hfl § *2.*

Vi ber om at alle henvendelser sendes inn via vår saksportal: http://helseforskning.etikkom.no eller på e-post til: post@helseforskning.etikkom.no .

Vennligst oppgi vårt referansenummer i korrespondansen.

Med vennlig hilsen

May Britt Rossvoll
Sekretariatsleder

Veronica Sørensen
seniorrådgiver

Appendix 2

Appendix 3