A Comparative Three- and Bi-dimensional Research of the Marginal Fit of Pressed Lithium Disilicate Inlays

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The replacement of classical fillings, especially in the posterior area with different types of inlays has become a common solution used in order to improve all parameters which insure a long lasting treatment. Vrious ceramic materials and systems are available, but so far an ideal ceramic material suited for all clinical situations, has not been found. The range of ceramic materials as: lithium disilicate, aluminum oxide, zirconium oxide and hybrid ceramics enhance the possibilities of using ceramic inalys in various clinical situations. Marginal adaptation is one of the most important conditions for long-term success for any type of material. The marginal discrepancy of fixed restorations is one of the main factors which lead to failure of the prosthetic treatment.The purpose of the present study is to compare a 2D and 3D method for evaluating the marginal fit for pressed lithium dislicate inlays (Emax). The two used methods were: SEM-electronic microscopy and micro CT.

Keywords: marginal adaptation, pressed ceramic inlays, micro CT, SEM

The replacement of classical fillings, especially in the posterior area with different types of inlays has become nowadays a common solution used in order to improve all parameters which insure a long lasting treatment. Among other materials (gold, composites), ceramic inlays obtained through different techniques are used very often.

Marginal adaptation is one of the most important conditions for long-term success for any type of material. The marginal discrepancy of fixed restorations is one of the main factors which lead to failure of the prosthetic treatment. As shown in our previous studies [1,2], the accuracy of the restorations depends on many factors: a precise impression, a correct pouring technique of the dies, an accurate wax pattern, as well as a flawlessly cementation technique.

Nowadays various ceramic materials and systems are available, but so far an ideal ceramic material suited for all clinical situations, has not been found. The great range of ceramic materials as: lithium disilicate, aluminum oxide, zirconium oxide and hybrid ceramics enhance the possibilities of using ceramic inalys in various clinical situations.

CAD CAM technique has the major advantage of decreasing technical and clinical error due to specific fabrication technology. There are studies in the literature that are focused on a comparison between different restorations obtained through the conventional methods and CAD/CAM manufacturing [3, 4]. According to D'Arcy [5] CAD/CAM manufactured inlays offer a higher production accuracy which implies also a better marginal fit.

From a clinical point of view, of great importance is the design of marginal preparation (6-7), the angulation of the vertical walls [8] as well as the use of a compatible adhesive system [9].

The purpose of the present study is to compare a 2D and 3D method for evaluating the marginal fit for pressed lithium dislicate inlays (Emax). The two used methods were: SEM-electronic microscopy and micro CT.

Experimental part

Materials and method

For our research we used four healthy upper molars, which were extracted for orthodontic reasons. We stored the samples in artificial saliva at 4æ%C for less than 6 months. We tried to standardize the preparation method and used the same preparation steps following the general guidelines for inlay preparations, as we used other three studies. As part of a larger study first class inlay cavities were prepared in the same manner as in the researches regarding BioHPP and Emax pressed inlays. We used high speed carbide burs (iSmile, Sacramento, Canada) with a 0.3 mm tips for entering into the cavity and for establishing the pulpal floor at a depth of 2.5 mm FG271. The use of a FG169L (SS White, New Jersey, USA) high speed bur with a tip thickness of 0,5 mm followed in order to extend the occlusal outline mesio-distally along the central groove, at a 3-5 degree divergence to the facial and lingual walls, and to accomplish the final extension in the triangular grooves. Last correcting of the enamel margins and the rounding of the internal edges was accomplished using a 6862 (Komet Dental, Lemgo, Germany) high speed diamond bur. All preparation steps were made at 350.00 rpm with an NSK turbine under constant cooling. For each tooth a pressed ceramic inlay (Emax) was manufactured (n=4).

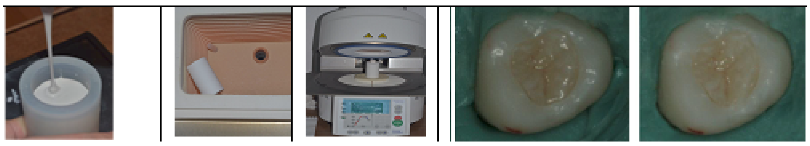

Fig. 1. Laboratory steps for fabricating pressed inlays; pressed inlays inserted into the cavities

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The following lab steps were the same as we run through in our previous Three-dimensional study regarding marginal evaluation of two pressed materials using micro-CT technology (10).

The milled leucite inlays placed into the cavities without being cemented were analyzed using a Skyscan 1172 desktop μCT scanner (Skyscan Bruker,Kontich, Belgium) at 80 kV, 100 μA using an aluminum and copper filter. The specimens were rotated 180° with a rotation step of 0.4° and an exposure time of 500 ms. The overall scanning time was approximately 75 min per specimen. The x-ray beam was pointed perpendicularly to the preparation long axis, and the image pixel size was 6.92 μm. SkyScan's volumetric reconstruction software (Nrecon) was used to reconstruct the x-ray projections and to create a set of cross section slices through the object which were saved as a stack of BMP-type files. The CTAn software (Skyscan, Aartselaar, Belgium) was used to obtain cross-section images through the center of the teeth (Z-axis) and also to perform measurements using the line measurement tool. The horizontal sections were made at the occlusal margin of each restoration, circumferentially, and the gap was analyzed by measuring the distance between the restoration and the tooth at each 100μ.

In order to make the scanning electronic microscopic examination, aluminium holders of 10 mm/Ø9 mm (from Bio-Rad, USA) were covered with carbon biadhesive tabs (from Electron Microscopy Sciences, USA) on which the four molars were positioned vertically keeping for all 4 samples enough distance to the lens of the microscope.

Next, a drop of colloidal silver (Agar Scientific, Austria) droped with an automatic pipette (200 μL) Brand (Brand GmbH, Wertheim, Germany) was used in order to establish electric conductivity between the surface of the coverslips and the metallic holders. The colloidal silver was dried and the holders were introduced in a Polaron E-5100 sputter coater. In the chamber of the sputter coater, under a high vacuum and an argon atmosphere, the teeth were covered with a thin layer of several nm of gold atoms (at 2400 V and 20 mA for 45 s [11].

SEM examination of the sputtered samples was carried out with a Jeol JSM-25S scanning electron microscope operating at 25 kV, and at magnifications of 45 x. The number of measurements was from 245 to 383, depending on the size of the circumference of the occlusal surface of each molar. The images were analyzed with the Olympus MicroImage Programme. Data were included in a statistical study.

We measured the lowest and the highest values for the E max pressed inlays with both analyzing methods, as well as the average values and standard deviation, for each of the four inlays.

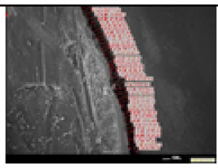
Statistical analysis was carried out on 8 columns of values (in two sets of 4). The results for the 8 inlays on the 4 molars were compared with One–way ANOVA with Tukey's Multiple Comparison Test performed using 5.00 for Windows (GraphPad Prism 5.00 Software, San Diego, California USA).The statistical program also expressed values by comparing each molar with others for both analyzing methods as well as for the same evaluation method.

Results and discussions

The lowest gap measured was found on the first molar when scanning with de electronic microscope (14.21μ). The highest score was found as well on the first molar when scanning with the electronic microscope (149.64).The compared results are shown in table 1 .

For SEM examination, the average values were: 80.93(M1), 70.68 (M2), 59.41 (M3), 82.20 (M4) and the standard deviation values were: 31.49 (M1), 30.43 (M2), 22.54 (M3) and 23.17 (M4). For micro CT examination the


Fig 2a. Samples fixed on the holders and mistured with colloidal silver. 2b samples sputterd with gold

Nr. Ms	SEM	Micro CT
M1	338	168
M2	254	144
M3	256	178
M4	266	121

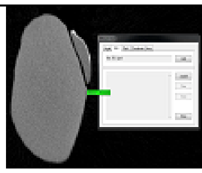
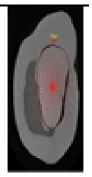



Fig. 3a .Comparison of measurements milled inlays using SEM and MicroCT image-horizontal section

Table 1

MINIMAL AND MAXIMAL GAP VALUES OBTAINED FOR MICRO CT AND SEM EXAMINATION

SEM	M1	M2	M3	M4	microCT	M1	M2	M3	M4
Min(μ)	14.21	14.41	22.09	24.02	Min (μ)	13.32	19.94	23.47	23.62
Max (μ)	149.64	142.65	129.18	129.41	Max (μ)	116.84	139.05	133.89	133.71

SEM Emax	Average	Std dev	microCT Emax	Average	Std dev
M1	80.93	31.49	M1	59.57	30.08
M2	70.68	30.43	M2	64.11	29.96
M3	59.41	22.54	M3	73.41	30.78
M4	82.20	23.17	M4	71.16	27.63

Table 2

AVERAGE AND STANDARD DEVIATION VALUES FOR SEM AND MICRO CT FOR EMAX INLAYS

EMAX CT1 vs EMAX SEM1	-21.5	11.4	Yes	***	-29.6 to -13.4
EMAX CT2 vs EMAX SEM2	-6.66	3.2	No	ns	-15.7 to 2.34
EMAX CT3 vs EMAX SEM3	14	7.18	Yes	***	5.57 to 22.4
EMAX CT4 vs EMAX SEM4	-11	5.04	Yes	*	-20.5 to -1.58

Table 3

TUKEY'S MULTIPLE COMPARISON TEST ONE-WAY ANALYSIS OF VARIANCE. COMPARISON GAPS FOR SEM AND MICRO CT PRESSED INLAYS ON THE SAME TOOTH average values were: 59.57 (M1), 64.11 (M2), 73.41 (M3) and 71.16 (M4) and the standard deviations were: 30.08 (M1), 29.96 (M2), 30.78 (M3), 27.63 (M4) (table 2).

For the statistical analysis One–way ANOVA with Tukey's Multiple Comparison Test was performed. When the marginal gaps of the inlays analyzed with 2D (SEM) and 3D (microCT) techniques on the same tooth were compared, the results had statistical significance in three out of four samples (M1, M3 and M4) while one comparison had no statistical meaning (M2) (table 3).

The program also expressed results by comparing the gaps measured with SEM vs microCT on different teeth, for example M1microCT vs M3 SEM. 11 out of 21 results had statistical significance (table 4).

The present study evaluates and compares a two dimensional and a three dimensional evaluating method of the marginal gap of pressed lithium disilicate ceramic.

There are many possibilies quoted in literature to measure the marginal fit of fixed restorations: visual examination, radiographic techniques, score-based stereomicroscopic quantification [10], SEM meaurements of light body silicone [11] or epoxy replicas with or without sectioning of the sample. Sometimes there is the need of embedding and sectioning of the restorations [12], or thermocycling and immersing of the specimens in basic fuchsin previous to sectioning [13].

Other studies [16] use OCT which exhibits micro-structural details that cannot be obtained with current imaging modalities. There is also the possibility of scanning the teeth with the help of efOCT) which allows the investigation of small quantities of materials of around 0.1 μg. and allows to establish the content of atoms and molecules and to perform semi-quantitative and quantitative analysis [17] or laser microspectral analysis [17]. The later method was used in the mentioned research for validation as we used SEM in the present study.

OCT can be used with or without contrast agents. OCT with contrast agents allows measurements of the gaps at a nanometric scale at the limit of inlay preparations [18].

For fixed restorations there are several methods for measuring the marginal fit. For example in five measuring locations as follows: the marginal gap, the chamfer area (for crowns), the axial wall, the axio-occlusal transition area, the occlusal area [19]. Other authors measure de external marginal gap of the restorations in 30 measuring points in the middle of the buccal and lingual surface [20]. Some researchersevaluated the marginal gap at at 6 points: at the mesiolingual line angle, midlingual, distolingual line

Table 4

TURKEY'S MULTIPLE COMPARISON TEST. COMPARISON OF GRAP VALUES BETWEEN ALL SAMPLES

ANOVA Table	SS	df	MS			
Treatment (between columns)	131000	7	18700			
Residual (within columns)	1370000	1718	797			
Total	1500000	1725				
Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff	
EMAX CT1 vs EMAX CT2	-4.63	2.04	No	ns	-14.4 to 5.17	
EMAX CT1 vs EMAX CT3	-13.8	6.44	Yes	***	-23.1 to -4.55	
EMAX CT1 vs EMAX CT4	-11.6	4.87	Yes	*	-21.9 to -1.31	
EMAX CT1 vs EMAX SEM2	-11.3	5.69	Yes	**	-19.9 to -2.71	
EMAX CT1 vs EMAX SEM3	0.161	0.0812	No	ns	-8.40 to 8.72	
EMAX CT1 vs EMAX SEM4	-22.6	11.5	Yes	***	-31.1 to -14.1	
EMAX CT2 vs EMAX CT3	-9.18	4.11	No	ns	-18.8 to 0.471	
EMAX CT2 vs EMAX CT4	-6.96	2.83	No	ns	-17.6 to 3.67	
EMAX CT2 vs EMAX SEM1	-16.9	8.49	Yes	***	-25.4 to -8.29	
EMAX CT2 vs EMAX SEM3	4.79	2.3	No	ns	-4.19 to 13.8	
EMAX CT2 vs EMAX SEM4	-18	8.72	Yes	***	-26.9 to -9.08	
EMAX CT3 vs EMAX CT4	2.22	0.946	No	ns	-7.93 to 12.4	
EMAX CT3 vs EMAX SEM1	-7.68	4.16	No	ns	-15.7 to 0.287	
EMAX CT3 vs EMAX SEM2	2.52	1.3	No	ns	-5.89 to 10.9	
EMAX CT3 vs EMAX SEM4	-8.82	4.57	Yes	*	-17.2 to -0.481	
EMAX CT4 vs EMAX SEM1	-9.91	4.68	Yes	*	-19.0 to -0.770	
EMAX CT4 vs EMAX SEM2	0.302	0.137	No	ns	-9.22 to 9.83	
EMAX CT4 vs EMAX SEM3	11.8	5.34	Yes	**	2.24 to 21.3	
EMAX SEM1 vs EMAX SEM2	10.2	6.16	Yes	***	3.05 to 17.4	
EMAX SEM1 vs EMAX SEM3	21.7	13.1	Yes	***	14.5 to 28.8	
EMAX SEM1 vs EMAX SEM4	-1.13	0.693	No	ns	-8.20 to 5.94	
EMAX SEM2 vs EMAX SEM3	11.4	6.48	Yes	***	3.81 to 19.1	
EMAX SEM2 vs EMAX SEM4	-11.3	6.48	Yes	***	-18.9 to -3.78	
EMAX SEM3 vs EMAX SEM4	-22.8	13	Yes	***	-30.3 to -15.2	

angle, distobuccal line angle, midbuccal, mesiobuccal line angle [21]. There are several techniques, used in different researches which measure the gap at the internal, at the external limit of the shoulder preparation, at 100, 200 or 300 or even at 500microns [22].

For inlays the method of measuring included first establishing the occlusal circurmference of the inlay and then tracing perpendicular lines starting from the circumference line to the margin of the inlay in variable steps.

As it can be seen, for fixed dentures an absolute algorithm has not been established yet. The drawback consists in the lack of uniformity in measuring the distance between the tooth and the limit of the prosthetic restoration [23].

The microCT technique can encount problems at scanning at high resolution, depending of the volume of the examend tooth as well a of the detector size. When using maximum magnification part of the specimen can be outside of the field of view. The microCT evaluation method has the main advantage of beeing a noninvasive contactless examination wich provides accurate results at a micrometric scale through the 3D images. The SEM evaluation on the other hand has lower costs, for analyzed inlays there is no need for sectioning the samples, no need for repositioning of the samples because the evaluation has been made only before luting.

Conclusions

When reviewing the literature one can see that there is rather a range of values than one single specified acceptable value for the measurements of marginal gap for fixed restorations. Most authors agree that generally the marginal openings below 120 μm are clinically acceptable. Recent studies consider an acceptable fit around the value of 100 micrometers. An internal gap value of 200 to 300μ also may be clinically acceptable, but this requires in vivo confirmation.There is a large range of marginal fit values related to the location of a crown and type of restoration (20).

After gathering the data, we can conclude that within the limits of this study, the null hypothesis is rejected and there is a statistically difference among groups. We can also conclude that all measured gaps with the microCT technique were more accurate and the results were within clinically acceptable values and lower than those obtained by electron microscope scanning that were at maximal limit with SEM technique. The obtained data- the statistical difference- emphasizes the fact that the microCT technique is a more accurate technique than the SEM technique and produces more reliable results.

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