Three-dimensional Marginal Evaluation of Two Pressed Materials Using Micro-CT Technology

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The main goal of the present study is to compare the marginal fit of two different kind of pressed materials: a partially crystalline thermoplastic resin reinforced with ceramic particles (BioHPP) and lithium disilicate (EMax), through the use of the microCT technique. After extraction of four caries-free mandibular first molars, first class inlay cavities were prepared. For each tooth two inlays were manufactured- one by using BioHPP thermoplastic resin (n=4) and one by using Emax Press lithium disilicate (n=4). The marginal gap was analyzed circumferentially at the occlusal margin using a Bruker micro CT, by measuring the distance at the occlusal limit of the cavities, between the restoration and the tooth in several points for every surface of each tooth before cementing. Data were analyzed statistically using the Mann-Whitney U test and the Pearson's correlation coefficient (α=0.05). A significant statistical difference was found between the marginal gap size obtained for BioHPP and Emax inlays ($p<0.001$). For the Emax inlays the marginal gap had an average of 72µm, while for BioHPP the average was 94 µm. Both types of used materials offer a good marginal adaptation. By summing up the gathered data we can conclude that the pressed ceramics shows a better marginal fit than the pressed resin, probably because of the different processing methods: sintering versus polymerizing with different shrinkage values.

Keywords: marginal fit, Inlay, ceramic, resin, MicroCT

It is well known that a poor marginal fit of prosthetic reconstructions leads to marginal decays and to failure of the prosthetic treatment. In two previous studies we analyzed using SEM technique, the marginal gap of cast metal crowns using several waxing techniques and different cervical preparation techniques [1, 2]. Other macro- or microscopic nondistructive methods as penetrant liquids, silicone materials, and radiographic investigations can also be used for analyzing the final restorations and can lead to improvement of the quality of various prosthetic treatments [3[.

In addition to the marginal preparation technique and a fawless cementation technique, a proper conditioned ceramic surface is also basic conditions for a high surviving rate of the reconstructions [4].

The main goal of the present study is to compare the marginal fit of two different kind of pressed materials: a partially crystalline thermoplastic resin reinforced with ceramic particles (BioHPP) and lithium disilicate (EMax) through the use of the micro CT technique. The null hypothesis for our study was that there is no statistically significant difference between the two studied materials processed through the two manufacturing methods.

Experimental part

Materials and method

For the purpose of our study, we have used four caries free molars which were extracted for orthodontic purposes. After the extraction, the teeth were stored in 0.5% aqueous chloramine solution at 4°C for less than 6 months and first class inlay cavities were prepared following the general gidelines for inlay prepapartion [5] using a high speed carbide bur FG271(iSmile, Sacramento,Canada) with a 0.3 mm tip, which was used for entry and establishing the pulpal floor at a depth of 2.5 mm. Then a FG169L (SS White, New Jersey, USA) high speed bur with a tip thickness of 0.5 mm, was used to extend the occlusal outline mesio-distally along the central groove, at a 3-5 degree divergence to the facial and lingual walls, as well as to accomplish the final extension in the triangular grooves. The final step of the cavity preparation was performed using a 6862 (Komet Dental, Lemgo, Germany) high speed diamond bur which was used to correct the enamel margins and to perform the rounding of the internal edges. All preparation steps were made under constant water-cooling. For each tooth two inlays were manufactured- one inlay out of BioHPP (Bredent Gmbh &Co.KG, Senden, Germany) thermoplastic resin (n=4) and one by using Emax Press (Ivoclar Vivadent Inc., Amherst, USA) lithium disilicate (n=4).

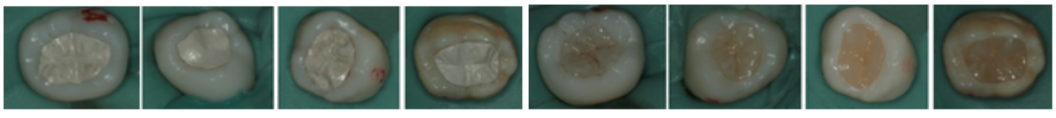

Fig. 1 Bio HPP and Emax Inlays inserted into the cavities

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The obtained inlays were placed into the cavities without cementation and the marginal gap was 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 irradiated perpendicularly to the preparation long axis, and the image pixel size was 6.92μm. The x-ray projections were reconstructed using SkyScan's volumetric reconstruction software (Nrecon) that uses the set of acquired angular projections to create a set of cross section slices through the object. Reconstructed slices 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 images were inspected and the marginal gap of each inlay was analyzed in horizontal sections, at the occlusal margin of each restoration, circumferentially, by measuring the distance between the restoration and the tooth in 100 μm steps.

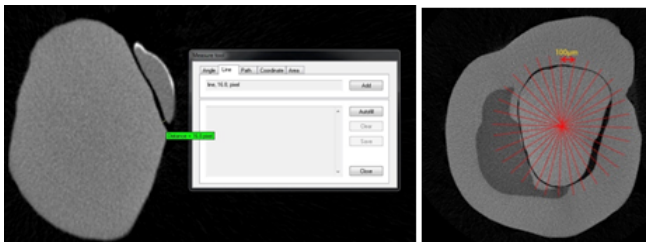

Fig 2. A. Measurement tool in CTAn Software ; b. Circumferential measurements

The number of measurements performed for Emax Press and BioHPP inlays on the 4 samples was: 168 and 151 for M1; 144 and 158 for M2; 178 and 167 for M3 and finally 121 and 165 for M4. The lowest and highest distance between the prepared tooth and the inlay was measured, as well as the average and the standard deviation and a statistical analysis was made. For each material, results from different measurement points were statistically analyzed using one way analysis of variance (ANOVA) and Tukey tests at a significance level of 5% using using GraphPad Prism 5.00 for Windows (GraphPad Software Inc, San Diego, California USA).

Results and discussions

The lowest and the highest measured values for the E max inlays 13.3 and 146.8μ were found both on the M1. On the second molar minimal and maximal values were 19.9 and 139.0μ, on the third molar 23.4 and 133.8μ and on the fourth 23.6 and 133.7μ (table 1).

For Bio HPP minimal and maximal values were: 31.9μ (on the forth molar) and 159.1μ on the second molar. The minimal and maximal values found on all four molars were: 34.4 and 145.3 on the first molar; 34.6 and 159.1μ on the second molar; 34.6 and 152.2μ on the third molar and 31.9 and 148.2μ on the fourth molar.

For E max inlays we obtained the following average values: 59.576 (M1), 64.115 (M2), 73.417 (M3) and 71.165(M4) and the following standard deviations: 30.087 (M1), 29.966 (M2), 31.786 (M3) and 27.634 (M4)- (table 5). For Bio HPP the average values were: 84.057 (M1), 91.469(M2), 87.597 (M3) and 68.061 (M4) and the standard deviations were: 35.538 (M1), 37.868(M2), 38.330(M3), 39.081(M4) (table 2).

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).

In two cases we obtained significant statistical values comparing the marginal gap of the two used materials on each tooth (molar 1 and molar 2), and in the other two cases we obtained no significant statistical values of the compared gaps (molar 3 and molar 4), as shown in figure.

The statistical program also expressed values by comparing each molar with others, displaying data for the same and different materials of the restorations. In 7 cases out of eighteen, the means were signifcantly different ($P < 0.05$).

The micro CT analisys used in the present study is from far the most reliable and modern method. It allows a non-destructive analysis of the restorations, allows 2D and 3D investigation of the marginal and internal gaps within the range of a few micrometers at multiples sites and directions [6]. Altough our study does not include $AgNO_3$ infiltration that penetrates and precipitates in very small gaps at the interface between dental tissue and the restorative material [7], the marginal fit was evaluated in the x- and y-axes, ensuring an objective perspective of the internal and marginal adaptation. However –as shown in other studies [6], is not possible to perform an accurate analysis in cases where insufficient radiographic contrast exists. As shown in other studies, although desirable, it is not always possible to scan at the highest resolution using the current desktop CT hardware, because both the detector size and sample size are determining the maximum magnification. When the magnification is further increased, part of the specimen will be outside of the field of view, creating streaking artifacts due to incomplete projections. As in other studies [8] the clinical procedures could not be fully standardized because of the anatomic variations of the teeth to be restored.

E max	M1	M2	M3	M4	Bio HPP	M1	M2	M3	M4
Min value(μ)	13.3	19.9	23.4	23.6	Min value (μ)	34.4	34.6	34.6	31.9
Max value(μ)	116.8	139.0	133.8	133.7	Max value (μ)	145.3	159.1	152.2	148.2

Table 1
MINIMAL AND MAXIMAL GAP VALUES OBTAINED FOR E MAX AND BIO HPP INLAYS

E max	Average	Std dev	Bio HPP	Average	Std dev
M1	59.576	30.087	M1	84.057	35.538
M2	64.115	29.966	M2	91.469	37.868
M3	73.417	31.786	M3	87.597	38.330
M4	71.165	27.634	M4	68.061	39.081

Table 2
Emax AND BIO HPP AVERAGE AND STANDARD DEVIATION

P value	P<0.0001				
P value summary	***				
Are means signif. different? (P < 0.05)	Yes				
Number of groups	8				
F	1121				
R squared	0.08509				
Bartlett's test for equal variances					
Bartlett's statistic (corrected)	23.08				
P value	0.0017				
Do the variances differ signif. (P< 0.05)	Yes				
ANOVA Table	SS	Df	MS		
Treatment (between columns)	81620	7	11660		
Residual (within columns)	877600	844	1040		
Total	959200	851			
Tukey's Multiple Comparison Test	Mean Diff.	Q	Significant?P< 0.05?	Summary	95% CI of diff
Molar1Emax vs Molar1Hpp	-24.48	6.716	Yes	***	-40.31 to -8.647
Molar2Emax vs Molar2Hpp	-27.28	7.693	Yes	***	-42.68 to -11.88
Molar3Emax vs Molar3Hpp	-14.08	4.307	No	Ns	-28.27 to 0.1200
Molar4Emax vs Molar4Hpp	3.104	0.8852	No	Ns	-12.13 to 18.33

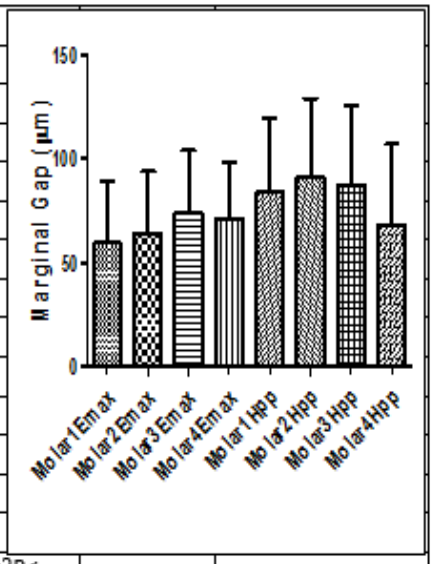

Fig. 3. Anova One-way Analysis of variance and statistical diagram for Emax and BioHPP inlays

Measuring circumferentially the gap provides a more accurate result then the five measuring location technique used by other authors [9, 6] although different studies showed that a large numer of gap measurements (230) reduced to 50 provide a less then 5µ variability in aritmetical means [10].

The limitation of the present study was the testing without cementation because of the radiopacity of the luting agent, which can alter the results of the measurements. This is considered a limitation of the micro-CT scan method.

Emax restorations provide clinically acceptable values regarding the marginal fit before as well as after cementation [11], (under 140 microns). It is widely accepted that for any kind of restorations the marginal gap increases after cementation [12]. This fact is shown in the above mentioned article emphasizing that the values of the marginal gap do not show significant augmentation after luting for inlay retained bridges in opposition to crown retained partial dentures.

In cemented restorations, interfacial stresses is generated by different stress or strain behaviours of the all-ceramic system, cement material and underlying tooth structure and is emphasized by discrepancies in the modulus of elasticity [13]. The present study does not include measuring the gap after cementation, however we obtained comparable average values of the marginal adaptation for the Emax inlays with values quoted in literature.

Another *in vitro* study [14] used SEM for estimating the clinical usability of adhesively luted three-unit posterior fixed partial dentures (FPD) made of a polyethylene-fiber-reinforced-composite (PFRC) and glass-fiber-reinforced-composite system (GFRC). The SEM analysis showed at least 80% of perfect marginal areas for both materials before and after thermal cycling and mechanical loading (TCML). Although our study does not include TCML tests, the measurements showed similar values compared to the study mentioned above.

Conclusions

The microstructure of IPS e.max Press consists of lithium disilicate crystals (approx. 70%), Li2Si2O5, embedded in a glassy matrix which provides very good mechanical properties as well as an optimum marginal fit. Nevertheless the most encounted complications quoted are related to the marginal and internal accuracy of the restorations and are chipping and the presence of secondary caries. Thus, an adequate fit is an important factor in the restorative treatment prognosis [6].

Bio HPP is a partially crystalline thermoplastic resin, reinforced with ceramic particles.

Altough it was expected that the Emax inlays would have a statistically significant superior fit compared to Bio HPP, predicting this result because of their different structures summed with the different processing methods (sintering vs polymerizing), the results showed that both materials offer a good marginal adaptation. Both pressing systems were able to successfully compensate the shrinkage due to sintering/polimeryzing, even in larger inlays.

Other investigation methods, as Confocal Microscopy Combined with Time Domain Optical Coherence Tomography [14, 15] can offer additional, valuable and more precise information regarding the marginal fit of esthtetic inlays, OCT images exhibiting microstructural detail that cannot be obtained with current imaging modalities.

As mentioned in literature [4], the main disadvantages of the microCT investigation method are radiation artifacts, which are caused by the differences in the coefficient of radiation absorption among the different materials.

By summing up the gathered 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 state that all measured gaps were within clinically values and that the pressed ceramic (acceptable

for clinical use: 156.83-180.21μm for inlays) [16] as well as pressed polymeric resins are materials which provide reliable prosthetic treatments.

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