The Influence of a Flexible Model on the Marginal Adaptation of Inlay Composite Restorations: A MicroCT Analysis

Keywords

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ABSTRACT

The aim of this study was to evaluate the influence of flexible models on the marginal adaptation of indirect resin composite restorations. Thirty-six cavity preparations were made for class II restorations in permanent molar teeth. Three groups (n=12) were defined following three impressions/model material combinations: G(STONE), polyvinylsiloxane, and type IV stone model, as a control group; G(IMPRESSIONPVS), alginate and flexible polyvinylsiloxane; G(MODELPVS), alginate and flexible polyvinylsiloxane for models. All restorations were positioned on their respective teeth and evaluated by micro-computed tomography. Absolute marginal discrepancies were measured digitally (ImageJ). The results were compared using one-way ANOVA (p< 0.05). The mean ± SD absolute marginal discrepancy of indirect resin composite restorations made from flexible and rigid stone models was as follows: G(STONE), 206 (±79.95) µm; G(IMPRESSIONPVS), 221.50 (±61.73) µm; G(MODELPVS), 203.25 (±65.93) µm. Absolute marginal discrepancies were not significantly influenced by the flexible and rigid stone models (p=0.78). The flexible or rigid stone model did not influence the marginal adaptation of the indirect resin composite restorations.

INTRODUCTION

In recent years, resin composites continue to be a highly versatile material for dental restorations due to their improved physical and chemical properties. They offer wear resistance, superior biomimetic characteristics, and better control of polymerization shrinkage.[1,2] It allows minimally invasive preparations and are easy to repair.[3,4] The composite restorations are applied mainly in two different techniques: direct and indirect.[5,6] Generally, which option to choose depends on the length of the cavity.[7] Direct restorations allow dental structure preservation and reduced polymerization shrinkage when the layering technique is used.[8,9] Poor interproximal contacts, surface roughness, microleakage, and postoperative sensitivity are still some drawbacks associated with direct restorations.[10,11] The indirect technique allows good occlusal anatomy, resin composite handling, and interproximal contours.[12,13] Besides, it provides reliable physical and mechanical properties due to the effect of the post-curing procedure.[14,15] However, an increased number of appointments is needed, and different materials are used to impression and replicate the cavity.[14,16]

In-office restorations have been proposed to overcome the increase of time for indirect restoration treatments that involve multiple appointments and laboratory work.[7,17] Several materials have been used for impression and model production, aiming to accelerate the indirect restoration treatment.[18] Polyvinylsiloxane (PVS) is traditionally used as impression material and type IV stone as a rigid model.[16,19] While PVS has dimensional stability and elastic recovery for reliable impression,[20] type IV stone has adequate abrasion resistance and minimal setting expansion.[21] This combination gives acceptable compatibility in terms of detail reproduction,[18] but requires time for casting, for setting and for the die-cutting process;[22] likewise requires two appointments, an use to provisional restoration and laboratory work leads to increased time and costs.[7] For this reason, flexible models become a great alternative, as it allows the combination of materials to obtain immediate models with quick polymerization,[18,23] reducing the time, and the technique sensitivity on the indirect restoration preparation.[24,25]

The combination of alginate and PVS may be used for in-office indirect restorations production.[18,26] Although alginate has reduced dimensional stability, it is easy to handle and has a low cost;[27,28] it is compatible with any stone or elastomeric casting material,[29] being a reliable alternative to be used as impression material for this application.[30] The PVS is used due to material stability, low shrinkage, and high detail reproduction capacity.[18,27] Considering these advantages, newly developed PVS were produced with high fluidity and optimum stiffness after curing.[31] These materials resulted in flexible models for easy and rapid indirect composite restoration reconstruction.[7,23] The quality of the impression and modeling are directly related to the adaptation of the restoration and with the long term success of the restorative treatments.[30,32]

The purpose of this study was to evaluate the influence of flexible models on the marginal adaptation of indirect resin composite restorations. The null hypothesis is that the model material will not influence the marginal adaptation of inlay restorations.

MATERIALS AND METHODS

STUDY DESIGN

Thirty-six cavity preparations were made for class II restorations in permanent molar teeth. The restorations were made on extracted human teeth with the respective informed consent of the patient (116-2019-POS8). Lower and upper third molar were selected when normal morphology and no superficial cavities were observed. Teeth with coronal fractures were excluded. The selected teeth were kept in saline solution at room temperature for up to 7 days,[33] followed by plaque removal and general cleaning.

The selected teeth were randomly assigned to three different groups according to the impression and model material combinations, as shown in Table 1 (n= 12). For control group (G_{STONE}), the prepared teeth were submitted to an impression with PVS and type IV stone was used to build the model. Alginate and flexible PVS were used to analyze the regular PVS as model material ($G_{IMPRESSIONPVS}$). Finally, alginate and flexible PVS for models were used to build models in $G_{MODELPVS}$ group.

Table 1. Impression and model material combinations

Group	Impression material	Model material
G_{STONE}	Polyvinylsiloxane	Type IV stone
$G_{IMPRESSIONPVS}$	Alginate	Polyvinylsiloxane
$G_{MODELPVS}$	Alginate	Polyvinylsiloxane for models

TOOTH PREPARATION

An initial impression was taken from each tooth's coronal portion using condensation silicone (Zetalabor®) for preparation a guide control. Teeth were prepared following the class II principles:[34] the isthmus width (a third of the buccolingual width) and occlusal box depth were prepared with 2mm; the mesial box was prepared with a 1 mm axial and gingival wall, 2mm above of the cement-enamel junction (CEJ). Round internal angles, slightly expulsive walls, well-defined margins were shown in Figure 1; all parameters of preparation were evaluated using a periodontal probe with the silicon matrix. One single operator performed all the preparations.

MODEL PREPARATION

The impression and model materials are presented in Table 1. All impressions and models were made for one single operator. The resin composite restorations were made by incremental technique with nano-filled composite (A2 shade; Filtek™ Z350 XT). For adequate polymerization, each 2 mm of resin was cured with a LED curing light for 20 s (Bluephase® N), with a power of 1200 mW/cm^2 *(Figure 2* and *Figure 3*). Finally, the inlay restorations were finished and polished with rubber cups (Jiffy®), flexible felt disks (Diamond®), and abrasive paste (Diamond R®) without invading the margin area.

MARGINAL ADAPTATION

Samples were scanned using a commercially available x-ray microcomputed tomography (MicroCT) scanner system (InspeXio® SMX-90CT Plus-Shimadzu). Before the scanning process, all restorations were visually evaluated to detect any defect. The restorations were manually placed on their respective tooth without any manual adjustment.

Each tooth was placed on a sample carrier, and its correct position on the screen was verified so that they could undergo a 360° rotation. The intensity of the x-ray was set at 90 kV and 80 uA at 14µm voxel size resulting in and 541 images. All images were converted into an 8 bit JPEG format and analyzed on

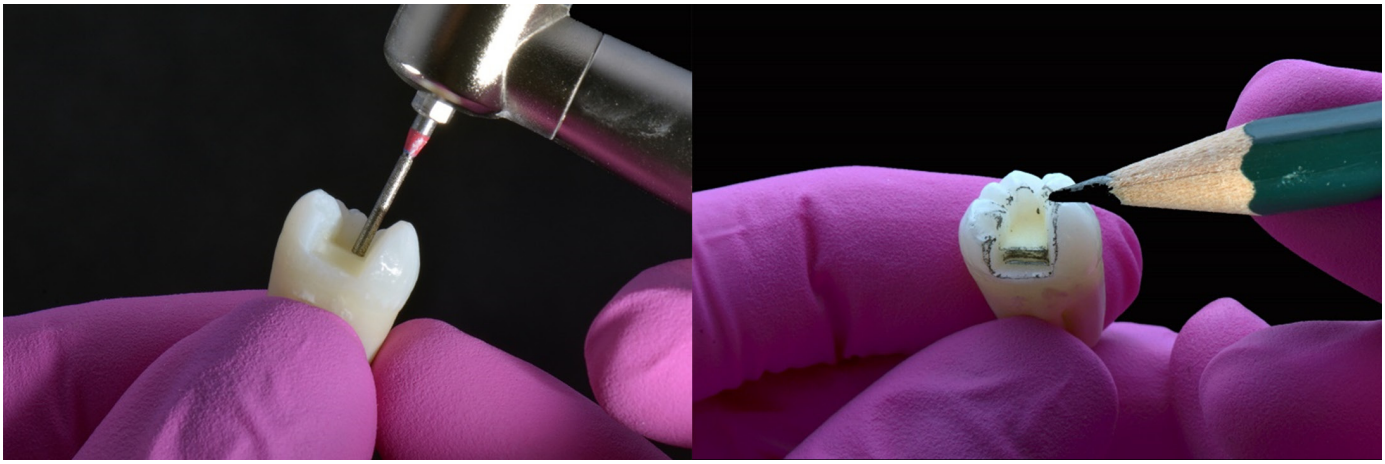

Figure 1: Tooth preparation for Class II indirect restoration.

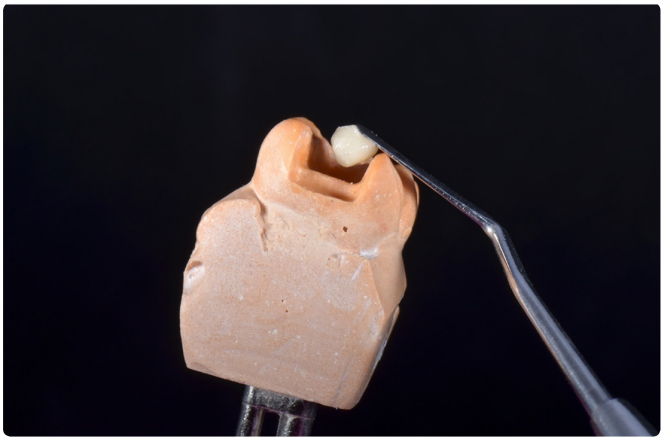

Figure 2: Incremental technique restoration.

an image software (ImageJ 1.51; NIH). The GAP size was evaluated on each tooth's palatal vestibule width was previously measured to set an accurate scale, and a range of 171 images was selected according to Figure 4. The center of the restoration was identified, and 85 images were selected on the vestibular and palatal regions. This selection was performed to obtain a stack of images where the restoration was placed.

The absolute marginal discrepancy (AMD) was measured on each image using a 300X magnification for a more accurate visualization of the distance between the finish line of preparation and the restoration margin.[35] The data was recorded as the length of the marginal discrepancy on each slice, and the results were shown as the average length for each measured point along with the defect, and the average marginal discrepancy per group. One single examiner performed a calibration for microCT measurement reliability after three independent measurements using the interclass correlation coefficient (ICC).

STATISTICAL ANALYSIS

The analysis plan was elaborated with the SPSS version 24 statistical program (IBM® SPSS® Statistics). The Shapiro-Wilk test was used to determine if there was a normal distribution in each study group. One-way ANOVA and Tukey test was used considering the normal distribution. All analysis were performed at a 5% significance level.

RESULTS

The ICC analysis showed a correlation of 0.95, with a lower limit of 0.88 (>0.7), confirming reliability for the measurements of the examiner. The mean and standard deviation of absolute marginal discrepancy of all groups are shown in Table 2. Figure 5 shows representative 3D reconstructions and high magnification images showing the AMD at class II restorations.

$G_{MODELPVS}$ showed the lowest means value, followed by G_{STONE} and $G_{IMPRESSIONPVS}$ groups. The one-way ANOVA detected no statistically significant difference between the absolute marginal discrepancy of flexible and rigid stone models ($p = 0.78$).

DISCUSSION

In-office indirect restorations may be an alternative for one appointment treatment depending on the operator's ability to make restorations with high quality and adequate margins.[17,30] Flexible models have been proposed for this immediate approach. In the present study, the absolute marginal discrepancy of flexible models was compared with stone models by microCT. The null hypothesis was accepted based on the results since the stone, and flexible models did not show significant differences in the AMD of inlay resin composite restorations.

Numerous studies evaluated the marginal discrepancy in indirect Class II restorations,[36,37] and there is no consensus on the maximum value of acceptable clinical discrepancy. Some variables, such as the tooth preparation, the material process, the study design, the measurement equipment, and the exact location of the tooth-restoration interface could influence the results.[38,39] A previous report established 120 µm as the limit for marginal disadaptation for ceramic crowns *in vivo*.[40] The American Dental Association recommends a maximum limit of 25 µm for Type 1 cements and 40 µm for Type 2 cements. However, these parameters also are rarely achieved and were established for water-based cements.[41] Boitelle and others[42] indicated that discrepancies could reach 545 µm in CAD-CAM restorations. The AMD was used here involving the vertical and the horizontal marginal discrepancies,[35,43] and the obtained average values

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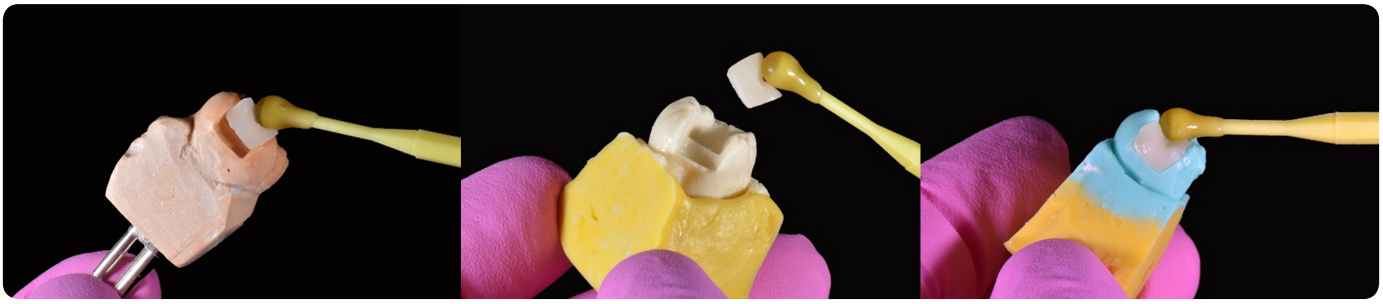

Figure 3: The restorations were performed in different impression/model materials: G_{STONE}, $G_{IMPRESSIONPVS}$ and $G_{MODELPVS}$.

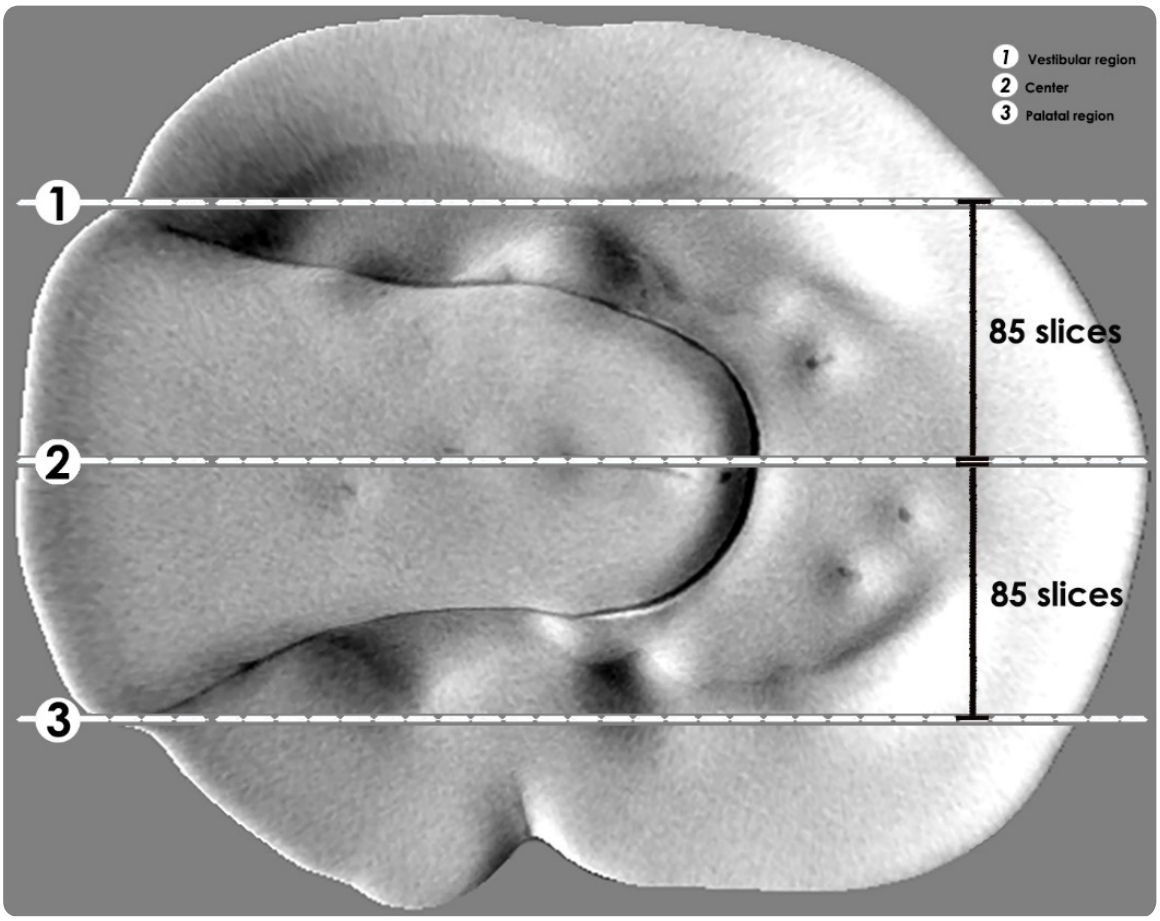

Figure 4: Representative MicroCT image and the delimited measured area. The center of the restoration was determined, and from this point, 85 slices were selected for the AMD measurement.

ranged between 203.25 µm and 221.5 µm. These results were in accordance with previous results where AMD was measured in microCT images.[44-46]

The AMD values found between different combinations of impression and model materials were not statistically significantly different *(Figure 5*; *Table 2*; p>0.05). The commonly used combination of PVS and type IV stone are known to produce accurate models due to the high dimensional stability and low shrinkage of PVS, which gives excellent detail reproduction.[20] These combination results in a time-consuming process for stone setting, die-cutting the model, and fabricating the restoration, which requires necessarily two appointments for the patient. For this reason, using the flexible model's technique may be useful to perform composite restorations in a single session.[17,30]

Considering the impression materials, PVS was used on the control group, while alginate was applied to the impression of cavities used on $G_{IMPRESSIONPVS}$ and $G_{MODELPVS}$. It is known that alginate has little dimensional stability, and this could lead to increased AMD due to lack of adequate detail reproduction, especially considering the Class II preparation and the need for adequate interproximal adaptation. Although this is well-established, in the present study, the alginate impression did not affect the AMD of produced restorations and may be used as an easy and inexpensive material for in-office indirect restoration production. Due to the increased stability and faster polymerization, PVS was applied in this study as model material as well, allowing the production of a model in a few minutes to in-office indirect restoration. PVS presents reliable dimensional stability, high detail reproduction, high

Table 2. Absolute marginal discrepancy (AMD)

Group	n	Mean (µm)	Minimum (µm)	Maximum (µm)	SD	P
G_{STONE}	12	206	120	343	79.95	
$G_{IMPRESSIONPVS}$	12	221.50	95	299	61.73	0.78
$G_{MODELPVS}$	12	203.25	123	395	65.93	

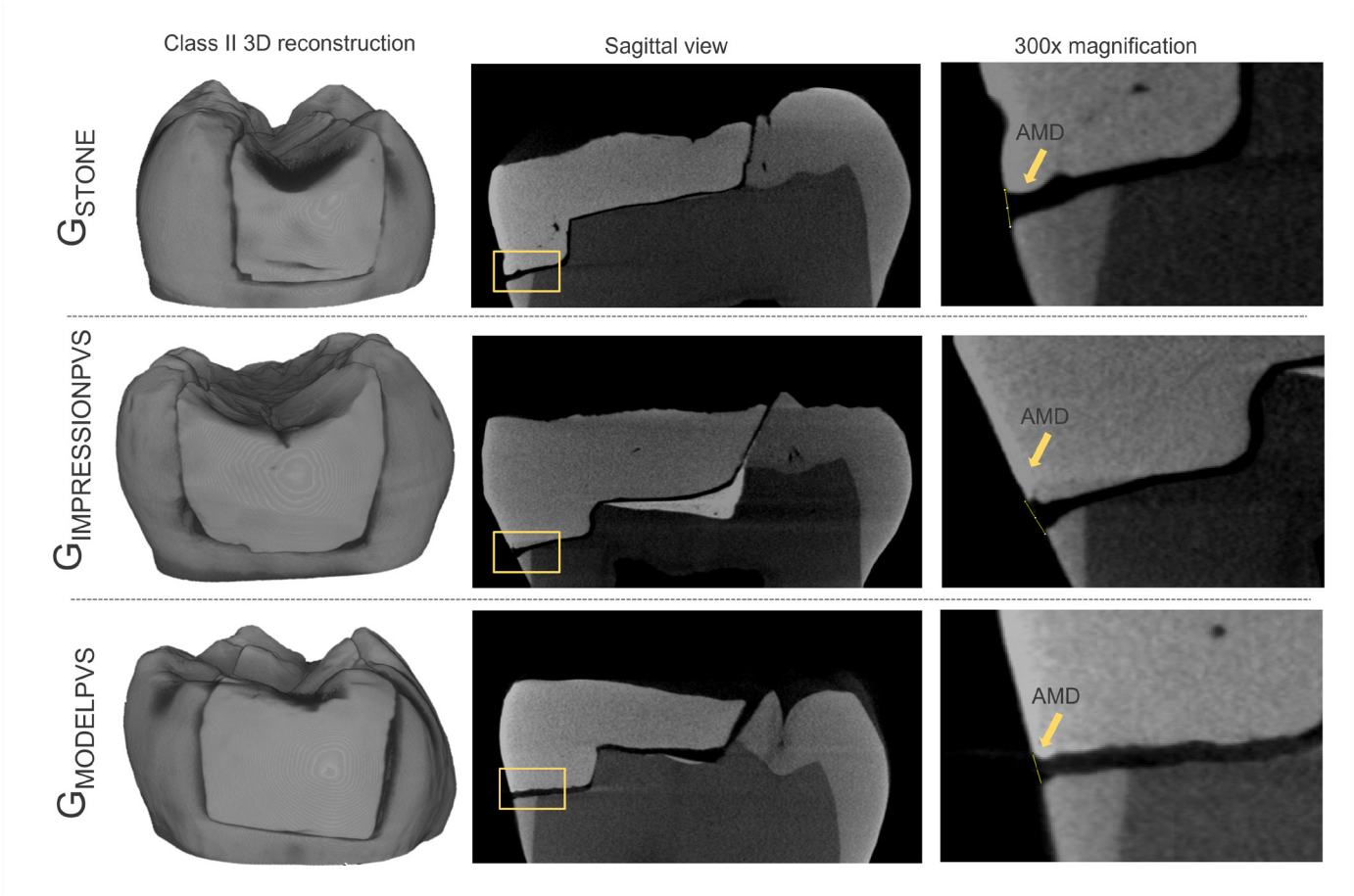

Figure 5: Representative 3D reconstructions for restored teeth with sagittal views showing the restoration limit where AMD was measured at 300x magnification.

accuracy, high tear strength, better elastic recovery, and short working time.[47] However, PVS is a hydrophobic material and suffers from inhibition of setting by sulfur-containing materials.[48] Another commercially available silicon model material was tested in the present study due to its low viscosity, low contact angle, better reproduction of preparations, and good stiffness after polymerization, allowing semi-rigid models and more stability incremental technique.[31,49] These advantages could provide better results compared with flexible PVS, and this study showed the absolute marginal discrepancy was similar for all kinds of die materials (*Table 2*; >0.05).

The marginal adaptation is measured in different ways, and most of the techniques used for quantification of the gap between indirect restorations and the tooth uses bidimensional views.[50] In this study, microCT was used to the analysis with a 2D image stack that was reconstructed as a 3D image,[51] allowing quantitative measurements in three dimensions.[52,53] One of the advantages is easy to obtain digital sectional slices in any direction, depending on the parameter to evaluate. Although the technique is theoretically feasible and reliable, it also requires prior training-calibration with the examiner's software management. Future studies should integrate guidelines to increase the automation of the measurement process. The microCT analysis was performed before sample cementation to compare the restoration's proper seating according to the fabrication technique. The influence of impression and model material in cemented restorations may be evaluated considering the influence of the AMD values' cementation material.

The production of in-office indirect composite restorations may be used as an alternative for easy and faster one-appointment treatments for a complex and large length of the cavities, where direct restorations are not indicated. As different

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commercially available materials are used on the impression process and the model building, it is important to address the influence of these new alternatives in the parameter that may affect the restorative treatment quality, such as the marginal discrepancy. In the present study, the impression and the model material did not influence the adaptation of in-office inlay class II restorations.

CONCLUSION

The flexible model did not influence the marginal adaptation of the inlay resin composite restorations.

CONFLICT OF INTEREST

Authors declare that they have no competing interests.

MANUFACTURERS' DETAILS

- Polyvinylsiloxane: Panasil® Initial contact light and Panasil® Putty Soft, Kettenbach, Germany.
- Type IV stone model: Elite Rock Stone®, Zhermack, Italy.
- Alginate: Jeltrate Plus®, Regular set, Densply Sirona, USA.
- Flexible polyvinylsiloxane for models: Scan Die®, light, Yller, Brazil.
- Condensation silicone: Zetalabor®, Zhermack, Italy.
- Nano filled composite: Filtek™ Z350 XT, 3M Oral Care, USA.
- LED curing light: Bluephase® N, Ivoclar Vivadent, Liechtenstein.
- Rubber cups: Jiffy®, Ultradent, USA.
- Flexible felt disks: Diamond®, FGM, Brazil.
- Abrasive paste: Diamond R®, FGM, Brazil.
- X-ray microcomputed tomography scanner system: InspeXio® SMX-90CT Plus-Shimadzu, Japan.
- Image software: ImageJ 1.51; NIH, Maryland, USA.
- SPSS version 24 statistical program: IBM® SPSS® Statistics, New York, USA.

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