

P. Pott, A. Rzasa, M. Stiesch, M. Eisenburger

Department of Prosthetic Dentistry and Biomedical Materials
Research, Hannover Medical School, Hannover, Germany

e-mail: pott.philipp-cornelius@t-online.de

Marginal fit of indirect composite inlays using a new system for manual fabrication

ABSTRACT

Aim This *in vitro* study compares a new system for manual chair side fabrication of indirect composite restorations, which uses silicone models after alginate impressions, to CAD/CAM-technology and laboratory manual production techniques.

Methods and study design Each 10 composite inlays were fabricated using different types of production techniques: CAD/CAM-technology (A), the new inlay system (B), plaster model after alginate impression (C) or silicone impression (D). The inlays were adapted into a metal tooth and silicone replicas of the cement gaps were made and measured. Statistical analysis was performed using ANOVA and Tukey's test.

Results and Statistics In group A the biggest marginal gaps ($174.9 \mu\text{m} \pm 106.2 \mu\text{m}$) were found. In group B the gaps were significantly smaller ($119.5 \mu\text{m} \pm 90.6 \mu\text{m}$) than in group A ($p=0.035$). Between groups C ($64.6 \mu\text{m} \pm 68.0 \mu\text{m}$) and D ($58.2 \mu\text{m} \pm 61.7 \mu\text{m}$) no significant differences could be found ($p=0.998$), but the gaps were significantly smaller compared with group B.

Conclusion Chairside manufacturing of composite inlays resulted in better marginal precision than CAD/CAM technology. In comparison to build restorations in a laboratory, the new system is a timesaving and inexpensive alternative. Nevertheless, production of indirect composite restorations in the dental laboratory showed the highest precision.

Keywords CAD/CAM technology; Composite inlays; Indirect composite restorations; Marginal fit.

Introduction

The concept of minimally invasive therapy has become an important strategy in modern dentistry [Tassery et al., 2013; Walsh and Brostek, 2013]. Composite is an established material to fill small cavities. When children or disabled patients are treated, the treatment often has to be performed within a short time. The application of direct composite restorations can be very difficult in these situations. The main problem is to maintain a sufficiently dry field during the complete application time of the composite. Perugia et al. [2013] conclude that the method of immediate dentin sealing is sufficient for adhesive luting of indirect composite restorations. They found good hybrid layer with good adhesion properties after immediate application of dental adhesives before taking impressions. Furthermore polymerisation shrinkage of direct restorations is a persistent problem [Mantri and Mantri, 2013; Garcia et al., 2014; Bortolollo et al., 2013]. These problems might be reduced by the use of indirect fabrication of restorations. This procedure has been discussed in literature since the 1980s [Robinson et al., 1987; Cassin and Pearson, 1992; Plasmans et al., 1992; Cetin et al., 2013]. In 1992 Plasmans et al. [1992] studied the fabrication time which was needed to build indirect composite restorations using the ICS system. The overall mean time was 120 min. Mendonca et al., [2010] also evaluated the clinical success of direct and indirect composite restorations. After one year both types of restorations showed excellent clinical performance. In 2013, Cetin et al. evaluated the clinical success of direct and indirect composite restorations in posterior teeth after 5 years using the USPHS criteria and found no significant differences between both groups.

Because of the development and improvement of materials characteristics of modern composite-materials, indirect composite restorations attract interest again, especially in the field of paediatric dentistry as the working time in the patient's mouth can be reduced [Perugia et al., 2013; Koyuturk et al., 2013]. Moreover, in addition to a high survival rate, Koyuturk et al. [2013] found no significant differences in the survival rates between direct and indirect composite restorations, but direct restorations showed significantly higher values for marginal inaccuracy after six month. For the fabrication of indirect restorations, such as crowns, bridges or inlays, impressions are usually taken with silicone to obtain plaster models of the clinical situation. However, the high accuracy of silicon impressions needs sufficient patient's compliance. If children or special need patients are treated, this compliance might be reduced. An insufficiently dry field or movements of the patient during the setting time of the silicone can significantly diminish the quality of the impression. This problem can be overcome by using alginate as impression material. Guiraldo et al., [2012] found clinically acceptable detail reproduction and dimension accuracy on plaster-models

after alginate impressions. Sometimes treatment of children or patients with disorders has to be performed in general anaesthesia. If there is the need to place indirect composite restorations in these cases, the fabrication time has to be very short to reduce the time of narcosis. Using plaster to build models for these restorations extends the time until the restoration is ready, because it is not possible to build plaster models chairside or in the OR. An alternative system using alginate impressions in combination with a new model-silicone (GrandioSO Inlay System, VOCO GmbH, Germany, Cuxhaven) may be a timesaving alternative to silicone-impressions and plaster-models for indirect composite restorations.

The current study compares the marginal fit of indirect composite restorations built with this new system to CAD/CAM restorations (CEREC, Sirona, Germany, Bernsheim) and to restorations built on plaster models after silicone or alginate impressions. The following hypotheses were postulated: The marginal fit of inlays, produced on silicone models, is comparable to CAD/CAM inlays and to inlays made on plaster models, and the precision of alginate impressions is acceptable for fabricating indirect composite restorations.

Materials and methods

An artificial upper first molar (AG 3, Frasaco, Germany, Tettngang) made of resin was mounted into the corresponding model-base (standard working model AG3, Frasaco, Germany, Tettngang). A cavity for an MOD-inlay was prepared with preparation angles of 6°. The resin tooth was cast in metal (Phantom-Metal NF, Degudent, Germany, Hanau). A custom made restoration-positioning machine allowed the reproducible positioning of the restorations into the cavity. The machine consists of two functional parts: a clamp at the base and a movable cross head on which a fixation-adapter for the restoration was mounted via a 2D-hinge (Fig. 1).

Fabrication of the inlays

Table 1 shows the different groups for this study. In group A (n=10) inlays were fabricated by CAD/CAM-technology (Cerec, Sirona, Bernsheim, Germany) directly for the metal tooth. For each new inlay the metal tooth was cleaned up and prepared with scan-spray (zfx zircon scan, Xiondental, Munich, Germany) to reduce light reflection effects on its surface. The surface was scanned (InEos 3D, Sirona, Bensheim, Germany) and a digital model was calculated. The margins of the cavity were defined and the software submits a proposal of a CAD-design of the restoration. Then the restorations were milled with a digital preset spacer for the cement-gap of 50 µm (InLab MC XL, Sirona, Bernsheim, Germany; CAD Temp Monocolor CT-40, Vita Zahnfabrik, Bad Säckingen, Germany). In groups B, C and D each 10 composite inlays were made by hand. In group B alginate impressions

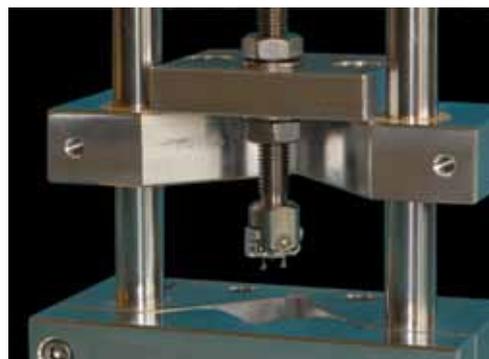


FIG. 1 Photograph of the functional parts of the custom-made restoration-positioning machine.

	Group A	Group B	Group C	Group D
impression material	direct scan of the metal tooth	alginate	alginate	silicone
model material	digital	silicone	plaster	plaster
fabrication technique	CAD/CAM	hand made	handmade	hand made

TABLE 1 The impression material, the model material and the production technique employed for the four groups A-D.

were taken, which were filled up with model silicone (GrandioSO Inlay System, VOCO GmbH, Cuxhaven, Germany). In group C alginate impressions were taken too, but the models were made of plaster. In group D the impressions were taken by silicone and the models were built of plaster (gold standard for FPDs). In groups C and D the spacer for the cement gap was defined by using a special spacing and isolating system (SIGNUM insulating Pen I and Pen II, Heraeus Kulzer, Hanau, Germany). According to the manufacturer's instructions a spacer for the cement gap was not necessary in group B. All of the handmade inlays were made with a horizontal layering technique using a composite material (GrandioSO, VOCO GmbH; Cuxhaven, Germany). Three layers were adapted for each inlay. Every layer was polymerised for 20 sec. All specimens were adapted to the cavity of the original metal tooth. Similar to the clinical situation, interference points between the restoration and the tooth had to be removed until the inlay could be easily positioned into the cavity.

Production technique of the silicone replica of the cement gap

The original tooth was fixed in the positioning machine. Each inlay was placed in the metal tooth and the cross head of the machine was lowered until the fixation-adapter came into contact to the inlay. The inlay was fixed with flowable composite (Tetric flow, Ivoclar Vivadent, Ellwangen, Germany) onto the adapter. Then the inlay could be removed from the cavity, and it was possible to replace it into the cavity without changing its position. The cavity was filled up with a light body silicone (Detaseal

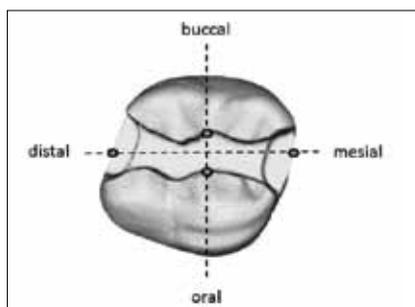
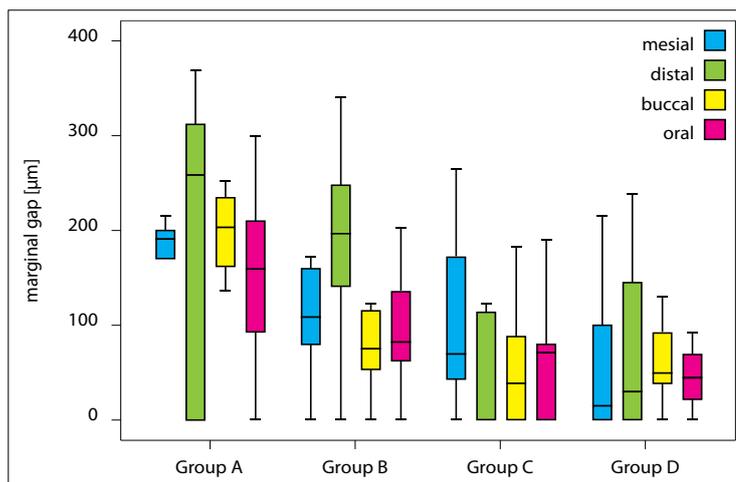


FIG. 2 Position of the measuring points.

FIG. 3 Marginal gaps on the measuring points mesial, distal, buccal and lingual for groups A (CAD/CAM), B (GrandioSO Inlay System), C (Alginate Impression and plaster model), D (silicone impression and plaster model).



bite, DETAX, Ettlingen, Germany) and the restoration was repositioned into the cavity. After the silicone had set, the restoration was lifted of the cavity. Thereby a thin silicone replica of the cement-gap adhered on the inlay.

Stabilisation of the silicone replica, definition of the measuring points and measurement

The tooth was removed from the positioning machine and a plastic box with two pairs of slots for a razor-blade was fixed in the positioning machine. The box was filled up with a medium body silicone (Dimension Garant L, 3M Espe, Seefeld, Germany,) and the inlay with the replica of the cement-gap was lowered into the silicone. After the medium body silicone had set, the composite restoration was removed and the replica of the cement-gap adhered to the medium body silicone. The remaining volume was filled up with medium body silicone, thus the replica of the cement gap was embedded completely and the silicone block was cut with a razor blade in four parts. Measuring points were defined at the mesial, the distal, the lingual and the buccal margins of the replica (Figure 2). High resolution photographs were taken of the silicone blocks of each specimen using a reflected-light microscope. Measurements were performed with the picture analysis software ImageAccess V09.4 (Imagic Bildverarbeitung AG, Glattbrugg, Switzerland).

Statistics

Statistical analysis was performed for each measuring point and for the mean over all measuring points. This was necessary because of the variation of the position of each composite restoration in the tooth. Statistical analysis was performed by ANOVA and Tukey's test. A p-value less than 0.05 was considered as statistically significant.

Results

The data showed high variation in all groups. In total, the handmade restorations seem to have better marginal precision than the CAD/CAM restorations. The data of

the four groups for every defined measuring point are shown in Figure 3. Statistical analysis showed significant differences between the groups at the positions "distal" ($p=0.013$), "buccal" ($p<0.001$) and "lingual" ($p=0.001$) and "mesial" ($p=0.068$). At the mesial measuring point there was a significant difference between groups A and D ($p=0.049$). Group C showed significantly lower marginal gaps at the distal measuring point than group A ($p=0.050$) and group B ($p=0.040$). At the buccal measuring point the marginal gaps in groups B, C and D were significantly lower than in group A ($p<0,001$). Group C ($p=0.010$) and D ($p<0.001$) showed significantly better precision at the lingual measuring point than group A. All of the other single comparisons are statistically not significant. Because of the big variation of the width of the marginal gaps within the four groups, for each specimen the mean of all four measuring points was calculated (Fig. 4). The highest marginal gaps were found after CAD/CAM-production ($174.9 \mu\text{m} \pm 106.2 \mu\text{m}$) in group A. The smallest marginal gaps could be seen in group D ($58.2 \mu\text{m} \pm 61.7 \mu\text{m}$). The marginal gaps in group B ($119.5 \mu\text{m} \pm 90.6 \mu\text{m}$) and group C ($64.6 \mu\text{m} \pm 68.0 \mu\text{m}$) were significantly smaller than in group A (B: $p=0.035$, C: $p<0.001$). Only between group C and D no statistical significance was found ($p=0.998$).

Discussion

The width of the marginal gap may be influenced by various factors during the fabrication of the inlays. In group A the precision of the CAD/CAM process depends on the digital scan [Schaefer et al., 2014] and the thickness of the scan-spray-layer, the preset space for the cement gap and the precision of the milling process [Hamza et al., 2013]. In groups B, C and D the precision of the impression, the impression material, and the quality of the model and the skill of the dentist may influence the fit of the restorations. The variation of the data at the four different positions may originate from two factors: Because of the cement-gap the inlays had a clearance fit in the cavity

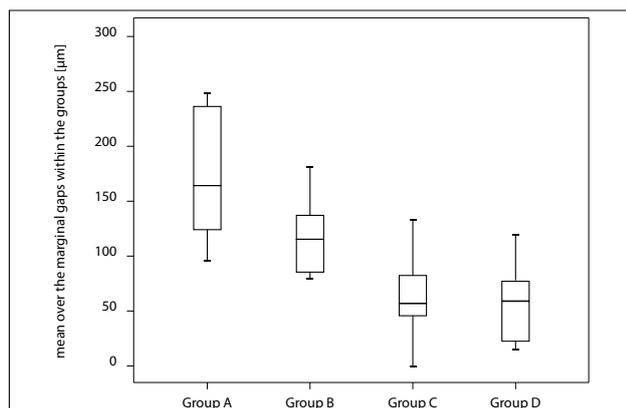


FIG. 4 Mean of the marginal gaps for groups A (CAD/CAM), B (GrandioSO Inlay System), C (alginate impression and plaster-model), D (silicone impression and plaster model).

of the original tooth. They could be slightly displaced even if they were fixed in the positioning machine. This could result in a perforation of the replica. In case of perforation, measurements at the opposite localisation were high. If the restoration had to be adjusted into the cavity using a rotating diamond bur, at these localisations the cement gap was larger than in the other areas. Because of the variation of the measured data at the four different points it was necessary to have a definition of the precision of the marginal gaps in total. Therefore the mean of the measured data was calculated for every group and statistical analysis was performed again. It could be seen that the marginal fit of restorations, built with the GrandioSO Inlay System (group B) was better than after CAD/CAM production (group A) ($p=0.035$). Precision of inlays made on plaster-models after silicone impressions (group D) is significantly better than the marginal gap in group B ($p<0.001$). As distinguished from group B, in group C instead of the silicone model a plaster model was used. The comparison of these two groups showed significantly smaller marginal gaps in Group C than in Group B ($p=0.036$). It could be followed, that the better precision depends on the plaster model. There was no significant difference between Group C and Group D ($p=0.988$). It could be inferred that the impression material has no influence on the width of the marginal gap. It can be deduced that the model material and not the impression material is the most important factor for the precision of indirect composite restorations.

Current literature that addresses the fit of indirect composite restorations is rare. Price and Gerrow [2000] evaluated the marginal gaps of indirect composite restorations and found spaces between $149.5 \mu\text{m} \pm 107.4 \mu\text{m}$ and $53.9 \mu\text{m} \pm 48.3 \mu\text{m}$. In 2006, Gemalmaz and Kükrer showed that the marginal fit of Class II ceromer inlays was $67.0 \mu\text{m}$ *in vitro*. Hanning et al. [1990] found marginal gaps between $280 \mu\text{m}$ and $350 \mu\text{m}$ for laboratory-finished composite inlays. The findings of the current study are in line with the literature.

The postulated hypotheses could be proved. In summary, handmade Class II composite restorations using

the GrandioSO Inlay System seem to be a good alternative to CAD/CAM restorations. In addition the GrandioSO System has the advantage of a short fabrication time and alginate as a suitable impression material. However, the clinical performance and the long-term survival of this system need to be monitored.

Conclusion

- Modern handmade indirect composite restorations showed better marginal fit than CAD/CAM restorations.
- There is no influence of the impression material on the marginal precision of handmade restorations.
- Extraoral fabrication can reduce the intraoral operating time in children or disabled subjects.
- Handmade indirect composite restorations with GrandioSO Inlay System (VOCO GmbH, Cuxhaven, Germany) can be a timesaving alternative to CAD/CAM techniques.
- Silicone is a fast alternative to plaster models, even though the precision of the restoration is minimally increased, the result is clinically acceptable.

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