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Three-dimensional accuracy of different techniques and materials for interocclusal bite registration

Philipp-Cornelius Pott[1*], Carolin Becker[1], Simone Schaumann[1], Lara Bühnen[1], Meike Stiesch[1], Michael Eisenburger[1]

Abstract

Objective: This study aimed to compare the precision of a temporomandibular joint (TMJ)-related bite-registration technique with the occlusion-related registration technique using various polyvinyl siloxane materials.

Methods: The interocclusal relation of 40 patients was transferred to stone casts by bite registrations using polyvinyl siloxane materials with different Shore harnesses (SH) values including Registrado clear (SH=70 A), Registrado xtra (SH=51 D) and Registrado scan (SH=90A). A joint-related registration technique (called the Gerber technique or gothic arch tracing) was also applied in all patents. The clinical contact situation and the contacts on stone casts were marked and transferred to a 3D-measuring software. The deviation of the occlusal contacts on the stone casts to the clinical reference was measured and compared between the registration methods.

Results: There was no statistically significant difference in contact deviation values between different types of registration methods (P=0.093). However, the frequency of missing contacts was significantly greater in the Gerber technique compared to the occlusion-related bite registrations (P<0.001). Gerber technique revealed greater deviations of the contact points in subjects with pain in TMJ and masticatory muscles. Irrespective of the registration technique, the patient-related factors including orthodontic pretreatment, treatment of TMD with occlusal splints, pain on palpation, joint noises, and restricted mandibular movement did not significantly affect the degree of occlusal contact deviation (P>0.05).

Conclusions: The hardness of the polyvinyl siloxane materials for occlusion-related bite registration did not affect the precision of the registration techniques in dentulous patients. Polyvinyl siloxane materials should be preferred for joint-related registration in TMD patients.

Keywords: Bite registration, Gothic arch, Hardness, Occlusion, Polyvinyl siloxane, Temporomandibular joint

Introduction

In the field of modern dentistry, the analysis of static and dynamic occlusion is important for diagnostic and therapeutic procedures (1-3). Jivnani et al. (4) demonstrated significant influences of temporomandibular disorders (TMDs) and functional parameters on interocclusal evaluations. Manufacturing dentures requires successfully transferring the interocclusal relation to the dental laboratory (5, 6).

Malocclusion can cause functional disorders of the masticatory system or result in damage to restorations, teeth or surrounding tissues (7). Because of the convex shapes of occlusal structures, horizontal misalignments accompany vertical effects, resulting in alternate positions of the lower jaw combined with shifting of occlusal contacts or even loss of contacts.

Different techniques for bite registration in centric or eccentric positions have been described in the literature and various materials have been introduced (8).

[1] Department of Prosthetic Dentistry and Biomedical Materials Research, Hannover Medical School, Hanover, Germany.

*Corresponding Author: Philipp-Cornelius Pott
Department of Prosthetic Dentistry and Biomedical Materials Research, Hannover Medical School, Hanover, Germany.
Email: Pott.Philipp-Cornelius@mh-hannover.de
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Occlusion-related techniques can be used in dentulous or partial dentulous patients. If there is no reproducible occlusion because of a shortened dental arch or a complex TMD, recording the occlusal relationship becomes challenging or impossible. In such cases, the intraoral tracing of the gothic arch, described by Professor Gerber (9-11), can be used for joint-related maxillo-mandibular registration. Recording the so-called gothic arch is a way for intraoral tracing of the lower jaw position in correlation to the upper jaw, taking into account the border movements. The joint-related registration is also necessary for patients who require vertical dimensional changes.

The high precision of the utilized registration technique is of great importance. The literature shows that digital registration techniques are not able to reproduce uniform occlusal contacts at their current state of technical development (12, 13). Zimmermann et al. (14) found comparable accuracies between digital scanning devices and conventional registration methods. Therefore, conventional bite registration with precision materials is still popular among clinicians.

Recently, polyvinyl siloxanes have been proposed for bite registration. They are similar to impression silicone materials but have been modified with plasticizing and catalyzing components to provide optimal flexibility and workability. Polyvinyl siloxane materials are available in different Shore hardness (SH) values. The SH value is a key factor for describing the hardness of rubber-elastic polymers and describes the penetration depth of a standardized test specimen into the material over time. The hardness of registration materials influences the accuracy of bite registration, by influencing the bite force intensity (15-17).

Besides the sensitivity of the registration techniques and materials, patient-specific factors can influence the precision of the transferred interocclusal relation (18-20). In 2021 Bapelle et al. (21) assessed the sagittal and transversal condylar inclination, and reported no significant influence of age, dentition and TMD symptoms on these variables, whereas class II division 2 malocclusion and increased vertical skeletal pattern showed significant influence on the sagittal condylar inclination.

Considering the mentioned factors, this clinical study aimed to evaluate the accuracy of interocclusal records using different bite registration techniques and materials. The following hypotheses were postulated:

1. In completely dentulous patients, the precision of occlusion-related registration technique using polyvinyl siloxane materials does not differ from the gothic arch tracing registered by joint-related Gerber technique (GT).
2. The hardness of the tested polyvinyl siloxane materials has no significant influence on the accuracy of the interocclusal records.
3. The accuracy of occlusal records does not depend on patient-specific factors such as "orthodontic pretreatment", "treatment of TMD with occlusal splints", "pathological findings during the palpation or the auscultation of the temporomandibular joint (TMJ)", and the "restricted mouth opening".

Materials and methods

Study design and participants

The protocol of this cross-sectional study was approved by the ethics committee of Hannover Medical University (No. 7389). Participants were recruited from the third-year dental students attending Hannover Dental School between January and April 2023. Participants were enrolled after signing informed consent forms. Partially edentulous individuals, cases with pathologic tooth mobility or those in urgent need of dental treatments were excluded from the study. The patients were also excluded if generating a reproducible occlusal relationship was not possible due to severe malocclusion.

Preparation of dental models

The polyvinyl siloxane impressions of both jaws were taken using a two-step putty-wash technique (Silagum Putty & Light; DMG, Hamburg, Germany). For each participant, stone casts (type IV dental plaster) of both jaws were produced in the dental laboratory. The stone cast of the upper jaws was mounted into the Protar V articulator (KaVo GmbH, Biberach, Germany) using the matching face-bow system.

Subsequently, the stone cast of the lower jaw was scanned by an intraoral scanner (CEREC AC Omnicam; Sirona, Bensheim, Germany) and orientated to the occlusal plane using CEREC 4.5 software (Sirona). A high-resolution 3D STL file was computed and exported to a 3D measuring software (3D-Tool GmbH & Co. KG, Weilheim, Germany). After that, a duplication mold (Adisil rosé; SIladent Dr Böhme & Schöps GmbH, Goslar, Germany) was produced to generate four replicas of the lower jaw stone cast.

Interocclusal relationship registration

Bite registration was performed by two techniques including the joint-related Gerber technique (GT) and the occlusion-related registration technique with various polyvinyl siloxane materials.

Technique 1 (Gerber technique): Individual registration appliances for the intraoral tracing of the gothic arch, were previously produced and prepared by each of the participants in the dental laboratory. The quality of these templates was checked by an experienced dentist. During clinical examination, the alignment of the occlusal contacts between both jaws was marked using Arti-Fol 8 µm (Bausch GmbH & Co KG, Köln, Germany). The dental arches with marked occlusal contact areas and a lateral view of the occluding teeth were scanned using a color-sensitive intraoral scanner (CEREC AC Omnicam), and a photograph of the situation was taken to document the clinical situation as control (Figure 1).

Technique 2 (Occlusion-related bite registration with polyvinyl siloxane materials): The following polyvinyl siloxane materials (all manufactured by VOCO GmbH, Cuxhaven, Germany) were used for bite registration in this study:

- Registrado clear (RC) with SH =70 A
- Registrado xtra (RX) with SH=51 D
- Registrado scan (RS) with SH=90 A

For all types of registration, the occlusal contacts were marked with Arti-Fol 8 µm on the lower jaw's stone casts (Figure 2).

Recording patient-specific factors

The presence or absence of the individual factors influencing occlusion was recorded for each patient. The factors were as follows:

1. *Orthodontic pretreatment:* A history of orthodontic therapy was recorded in the patient's file.
2. *Occlusal splint therapy for TMD:* Patients who currently wear or have previously worn occlusal splints for treating TMD were recorded.
3. *Pain on palpation:* If palpation of the TMJ and/or the masticatory muscles caused pain, it was recorded in the patient's file.
4. *Joint noises:* The presence of joint noises in the form of cracking or crepitation during auscultation was recorded.
5. *Restricted mouth opening:* Maximum mouth opening lower than 40 mm was considered a restricted opening and recorded.

Occlusal contact analysis

Figure 1. The clinical situation with marked contact areas (left), the intraoral scan with marked contact areas (right)

For each patient, four occlusal contact areas with the widest distance were defined as individual reference contact areas. An experienced dentist transferred the positions of the references and the corresponding contacts on the plaster models to the digital 3D model. Since occlusal contact points on teeth are not points in the mathematical sense, it was necessary to determine the central point in each contact area for further measurements. This results in contact pairs between the reference contacts and the corresponding contact points after each of the registration methods. The deviation between the contact areas and the corresponding reference areas was measured using the determined central points of each contact (Figure 3).

Depending on the amount of contact deviation, six categories were defined as follows:

- *A:* Deviation less than 0.05 mm *(matching contact areas)*
- *B:* Deviation less than 0.5 mm
- *C:* Deviation between 0.5 mm and 1.0 mm
- *D:* Deviation between 1.0 mm and 2.0 mm on the same cusp
- *E:* Deviation of more than 2.0 mm on the same occlusal field
- *F:* No detectable contact in the reference area. Thereby category F not only include maximal deviation but also loss of contact. Small mismatches in the vertical dimension also led to classification into category F.

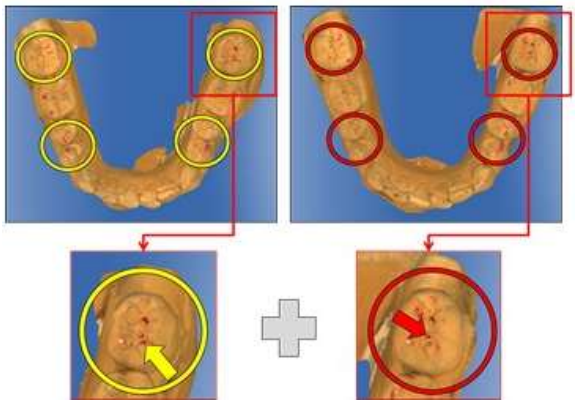

Figure 2. Marked occlusal contacts on stone casts after two different interocclusal records

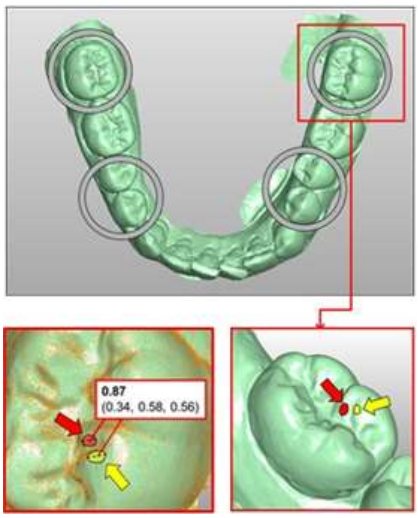

Figure 3. STL-model of a lower jaws stone cast with two transferred occlusal contacts in the 3D-measuring software

Sample size calculation and statistical analysis

Based on data provided by Ding et al. (15) and Keerthana et al. (16), a sample size of 40 participants was deemed necessary for this study. The Kolmogorov-Smirnov test showed a normal distribution of the data (P> 0.05). To compare contact point deviations between the groups, the data belonging to category F was excluded. ANOVA was run to detect any significant difference in compared contact areas between the study groups. The frequency of category F (missing contact) in the study groups was analyzed by the chi-square test. The influence of patient-specific factors on the registration accuracy was assessed by the independent samples t-test. The analysis was performed using SPSS version 25 (IBM Corporation, Armonk, USA), and the level of significance was set at P<0.05.

Results

Four reference areas were defined for each patient, resulting in 160 reference areas with 640 values in total. Figure 4 provides information about the distribution of categories A to F in different registration methods.

Initially, the qualitative accuracy of the registration methods was evaluated. Contacts referring to category F (n=221) were removed, as missing contacts in category F could skew the statistical analysis.

Table 1 gives information about the remaining contact deviation values belonging to categories A, B, C, D and E of each registration technique. The highest mean values were found in the GT group, and the lowest mean values were found in the RS group. ANOVA revealed no statistically significant difference concerning contact deviation values between the registration methods (P= 0.093; Table 1). However, the frequency of category F (no contact) was significantly different among the registration methods, with the Gerber technique showing a significantly higher percentage of missing contact among the other group (P<0.001).

Table 2 presents the influence of patient-specific factors on the degree of occlusal contact deviation in different methods. For this analysis, all categories (A to F) were evaluated, because the number of missing contacts belonging to category F might have been influenced by the factors to be evaluated. Regardless of the applied registration method, the amount of occlusal contact deviation did not significantly differ among patients who did and did not undergo orthodontic pretreatment (P=0.410) and the same goes for patients with or without a history of occlusal splint therapy (P=0.593). Similarly, the presence of pain on palpation (P=0.475), TMJ noises (P=0.932) and restricted mouth opening (P=0.741) did not significantly affect the amount of deviation of occlusal contacts (Table 2).

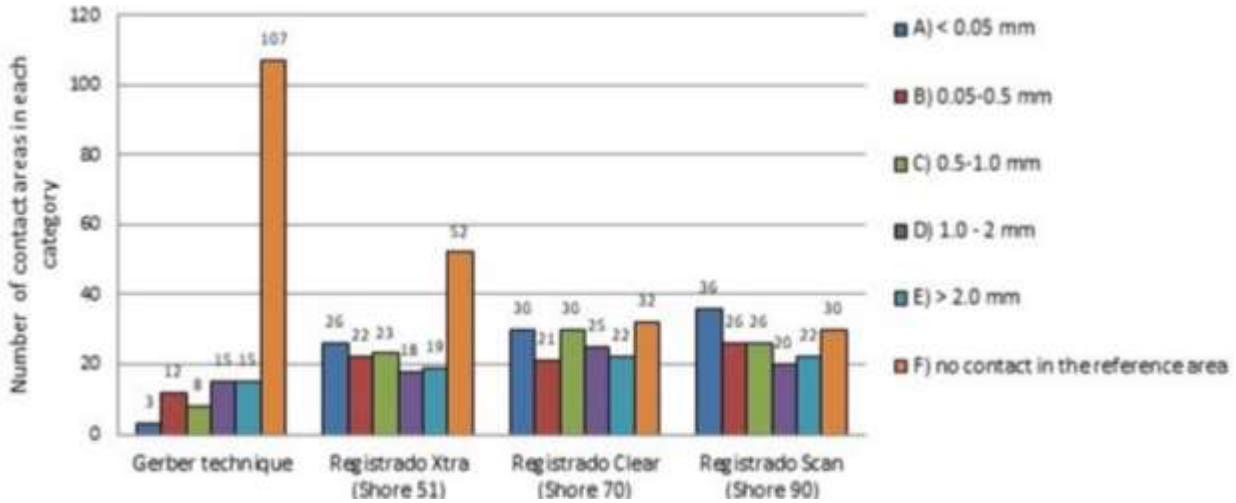

Figure 4. The distribution of compared contact areas in the six categories including A, B, C, D, E and F, sorted by registration methods

Table 1. Qualitative Analysis of the contact deviation values belonging to categories A-D in the study groups.

Type of registration	Mean ± SD [mm]	minimum [mm]	maximum [mm]
GT	0.77 ± 0.53	<0.05	1.90
RX	0.55 ± 0.53	<0.05	1.95
RC	0.58 ± 0.53	<0.05	1.90
RS	0.52 ± 0.56	<0.05	1.96
P-value	0.093		

N: Number of A-D categories, SD: Standard Deviation
GT: Gerber-Technique, RX: Registrado Xtra, RC: Registrado Clear, RS: Registrado Scan

When GT was used for registration, the aberration between the identified contacts and their reference areas tended to increase in patients with pain during the palpation of TMJ or masticatory muscles, and it was lower in patients with normal mouth opening (Table 2).

Discussion

Based on the data found in this study, the hypotheses posed can be answered as follows: The first hypothesis was partially confirmed. There was no significant difference in the contact point deviations among the registration methods. However, GT showed slightly higher deviation values compared to the RX, RC and RS, GT, and the frequency of missing contacts (category F) was significantly greater in the GT technique.

The second hypothesis was confirmed. The hardness of the tested polyvinyl siloxane materials did not influence their accuracy of bite registration, because the contact point deviations in categories A to E were not significantly different among the registration methods.

The third hypothesis can also be confirmed. Orthodontic pretreatment had no significant influence

Table 2. Mean and standard deviation (SD) of the aberration between the contact areas and their references in different registration methods, sorted by the presence or absence of patient-specific factors that may influence bite registration (Gerber-Technique (GT), Registrado Xtra (RX), Registrado Clear (RC) and Registrado Scan (RS))

Influencing factor	Method of registration	aberration between the contact areas and their references [mm]		(p-value)
		mean ± SD	mean ± SD	
Orthodontic pretreatment		Yes (31 patients)	No (9 Patients)	
	GT	1.79 ± 1.79	1.26 ± 0.92	0.302
	RX	1.18 ± 1.44	0.81 ± 1.07	0.236
	RC	1.08 ± 1.27	0.95 ± 0.96	0.606
	RS	1.14 ± 1.51	0.75 ± 0.99	0.184
	Total	1.29 ± 1.5	0.94 ± 0.98	0.410
Treatment with occlusal splints		Yes (21 Patients)	No (19 Patients)	
	GT	1.56 ± 1.52	1.76 ± 1.74	0.650
	RX	0.92 ± 1.10	1.30 ± 1.64	0.157
	RC	1.01 ± 1.10	1.10 ± 1.33	0.694
	RS	0.91 ± 1.20	1.20 ± 1.60	0.244
	Total	1.10 ± 1.23	1.34 ± 1.57	0.593
Pain on palpation		Normal (32 Patients)	Pathology (8 Patients)	
	GT	1.48 ± 1.53	2.47 ± 1.86	0.097
	RX	1.08 ± 1.40	1.13 ± 1.26	0.871
	RC	0.98 ± 1.11	1.34 ± 1.52	0.190
	RS	0.99 ± 1.43	1.32 ± 1.35	0.303
	Total	1.13 ± 1.36	1.56 ± 1.49	0.475
Joint noises		Normal (21 Patients)	Pathology (19 Patients)	
	GT	1.47 ± 1.52	1.98 ± 1.75	0.272
	RX	1.14 ± 1.47	1.02 ± 1.24	0.651
	RC	1.15 ± 1.21	0.94 ± 1.19	0.327
	RS	1.06 ± 1.46	1.04 ± 1.38	0.928
	Total	1.20 ± 1.42	1.24 ± 1.39	0.932
Restricted mouth opening		Yes (29 Patients)	No (11 Patients)	
	GT	1.81 ± 1.71	0.97 ± 0.88	0.144
	RX	1.05 ± 1.29	1.21 ± 1.58	0.593
	RC	1.09 ± 1.20	0.93 ± 1.22	0.511
	RS	1.00 ± 1.24	1.19 ± 1.78	0.487
	Total	1.23 ± 1.36	1.07 ± 1.36	0.741

on the accuracy of the individual bite registrations. Functional therapy with occlusal splints also had no significant influence on the accuracy of the individual bite registrations. Pathological findings in the temporomandibular joint detected by palpation or auscultation also did not lead to significant changes in transmission accuracies. Restricted mandibular movement also had no significant influence on the transmission accuracy of the individual registrations.

All of the participants of this study were dental students who knew occlusion and registration techniques. The study benefited from high patient compliance during registrations, which helped reduce patient-specific errors. In contrast, patients in the clinical setting usually are not trained to find correct occlusion, which can result in registration errors. Patients with, for example, temporomandibular disorders are sometimes trained to find a muscularly balanced position of the mandible (22, 23). Unfortunately, if the patient's habitual position of the mandible is not compatible with the centric condyle position or the position at maximum intercuspation, these training effects might be responsible for inaccurate registrations.

Some procedural errors might have occurred during the processing of the stone casts. Class IV plaster, which is also used as an accurate material for denture fabrication, was used for the stone casts. To minimize inaccuracies from intraoral scans, this study utilized conventional polyvinyl siloxane impressions to fabricate stone casts for participants. In each case, the stone cast of the subjects resulting from the clinical impression was scanned at the highest possible resolution. The resulting digital 3D models were used for measuring the contact point displacements. This provided high precision for measurements. The STL data set was not rendered during export to avoid a reduction of the resolution. As the STL file could be imported into the measuring software, measurements could be performed at maximal resolution.

Because of the individual occlusion pattern of each participant, it was not possible to define identical contact points for the measurements. The mobility of each participant’s mandible has an individual effect on the deviation of occlusal contacts. Considering these factors, the four individual reference contact areas were identified intraorally for every participant by searching those contacts with the widest distances between them. For a description of the contact deviation during the experimental analysis, categories A to F were defined, describing the alteration of each experimental contact compared to the corresponding reference contact. Due to the non-automatic transfer of the contact areas into the 3D measuring software, minimal transfer errors cannot be excluded.

The amount of deviation of contact areas from their respective reference points for the three occlusion-related bite registrations including RX (0.55 ± 0.53 mm), RC (0.58 ± 0.53 mm) and RS (0.52 ± 0.56 mm) were very similar. The joint-related registration technique (GT) showed a mean contact deviation of 0.77 ± 0.53 mm, which was slightly greater than that of RX, RC, and RS. Furthermore, the frequency of missing contacts in the Gerber technique was significantly greater than the occlusion-related registration. Utz et al. (24) compared the reproducibility of different recording materials and found variations between 0.14 ± 0.16 mm and 0.31 ± 0.23 mm. Ten years later Utz et al. (25) evaluated the accuracy of check-bite registrations made of wax or acrylic wafers and found deviations from 0.33 to 0.44 mm. Jaschouz and Mehl (26) evaluated the reproducibility of digital bite registration at four different times within a day and found variations equal to 42.0 ± 34.0 µm.

Tracing of the gothic arch revealed greater deviations of the contact points in subjects with pathological changes in the TMJ and lower deviations in patients with normal mouth opening. This could be because TMD patients did not have a physiological centric condylar position, even if the clinical examination did not show TMD symptoms with a need for treatment. In the technique of Prof. Gerber, the centric condylar position is registered and transferred to the stone casts accordingly. The outcomes of this study indicate that in patients with TMD symptoms, occlusion-related bite registration reduces the deviation between upper and lower jaw plaster models in the articulator compared to the orientation of the models by the Gerber technique. The joint-related registrations may be helpful in TMD diagnosis to identify mismatches in jaw relations, independent of occlusion.

The outcomes of this study are consistent with the findings of Obrez and Stohler (27) who showed that pain has a significant effect on the precision of gothic arch tracing. Todic et al. (1) evaluate the influence of craniomandibular disorders on the precision of gothic arch tracing in 200 subjects. They found less amplitude of lateral and protrusive mandibular movement and lower size of the gothic arch in patients with pathologic TMJ symptoms compared to healthy subjects.

The limitation of this study was the small sample size. Further research is needed to compare the accuracy of

registration techniques in patients with different classes of TMD. The measurement method used in this study should be validated in further studies using larger sample sizes.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1- There was no statistically significant difference concerning contact deviation values between different registration methods. However, the frequency of type F category (missing contacts) was significantly greater in the Gerber technique compared to occlusion-related bite registrations with various polyvinyl siloxane materials.

2- The hardness of the polyvinyl siloxane materials (Registrado clear, Registrado xtra and Registrado scan) did not influence the precision of bite registration in completely dentulous patients.

3- Regardless of the registration method, the presence of patient-specific factors (orthodontic pretreatment, treatment of TMD with occlusal splints, pain on palpation, joint noises, and restricted mouth opening) did not significantly affect the amount of occlusal contact deviation.

Conflict of interest

None declared.

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