Revista
ESTOMATOLÓGICA
Herediana
E-ISSN 2225-7616

REVIEW ARTICLE
DOI: https://doi.org/10.20453/reh.v36i1.6198

Methods for obtaining interocclusal records: a comparative review of analog and digital methods

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ABSTRACT

Interocclusal record registration is a fundamental procedure in dental practice, both during the diagnostic phase and throughout prosthetic rehabilitation. However, conventional methods present significant challenges related to material handling, patient cooperation, and operator skill. Factors such as material dimensional instability, articulator manipulation, and model storage may compromise the accuracy of the final mounting. In this context, the incorporation of CAD/CAM technologies has made it possible to overcome several analog limitations and optimize the clinical workflow, although this technology continues to evolve. The aim of this article is to conduct a literature review on the accuracy of digital interocclusal records compared with analog ones, in order to provide updated evidence that may guide clinicians in selecting the most appropriate technique for occlusal analysis in each case.

Keywords: dental materials; computer-aided design; digital technology; interocclusal records.

Received: January 7, 2025
Accepted: December 4, 2025
Online: March 16, 2026

Cite as:
Lau V, Balarezo JA, Díaz EA. Methods for obtaining interocclusal records: a comparative review of analog and digital methods. Rev Estomatol Herediana. 2026;36(1):e6198. doi:10.20453/reh.v36i1.6198

INTRODUCTION

In the ninth edition of the Glossary of Prosthodontic Terms, an interocclusal record is defined as the "registration of the positional relationship of the opposing teeth or arches" or the "record of the positional relationship of the teeth or jaws to each other" (1,2). Its clinical importance lies in facilitating occlusal analysis to establish an accurate diagnosis, determine an appropriate treatment plan, and fabricate prostheses or restorations under a specific occlusal scheme.

Accuracy in this procedure is critical; an erroneous record may result in inaccurate model mounting, which would require significant clinical adjustments to the final restoration. In cases of greater discrepancy, complete repetition of the procedure may be required, generating negative economic and time-related consequences for the dentist, dental technician, and patient (1).

In modern medicine and dentistry, the intraoral scanner has become an essential tool. This device integrates a composite hardware system (camera and computer) with software that enables the capture of 3D geometries, generally reconstructed in STL and PLY formats. Nowadays, different technologies are available for surface scanning. Among these, triangulation stands out and is incorporated into systems such as CEREC Omnicam (Dentsply Sirona) and Medit i700 (Medit Corp.). This technology operates by calculating the position of a point in space through the intersection of known angles and distances from two reference points. Another technology is confocal microscopy, used in devices such as iTero Element 2 (Align Technology) and TRIOS 3 and 4 (3Shape). This method captures images at different focal depths to filter and reconstruct surfaces with high sharpness. Similarly, active wavefront sampling, employed in the 3M ESPE Lava C.O.S. system, is characterized by the capture of images through an aperture that is offset from the optical axis. Finally, stereophotogrammetry estimates spatial coordinates (x, y, z) using image-analysis algorithms and passive light projection, as exemplified by devices such as Vectra 3D (Canfield Scientific).

Despite the considerable advantages offered by these systems, direct digital impression acquisition presents limitations in complex clinical scenarios, such as capturing deep subgingival margins, the presence of highly reflective structures, or interference from fluids such as saliva or blood. Under these circumstances, the indirect workflow—conventional analog impression followed by digitization using a desktop scanner—remains a necessary alternative. Desktop or laboratory scanners are notable for their high precision, rapid processing speed, and lower cost compared with intraoral devices. However, their principal limitation lies in dependence on a physical model, requiring impression and gypsum materials and thereby introducing error variables associated with material contraction, expansion, and manipulation. From a technological standpoint, contact scanners (mechanical scanners using a probe) exist, although they have been replaced by optical scanners because of the risk of damaging the model surface. Among optical systems, structured white-light scanners predominate. These devices project multiple fringe patterns and offer advantages in capturing fine details compared with laser scanners that analyze linear patterns (3).

Moreover, another relevant concept associated with interocclusal recording materials and scanning technologies is precision. According to the Royal Spanish Academy (RAE), "precision" is defined as the "quality of being precise" (4), whereas "precise" refers to something "perceived clearly and sharply" or to a person "acting with wise decision and skill" (5). This term is frequently confused with others, such as "trueness" or "accuracy," as they are closely related concepts. For example, "accuracy" may be understood as the combination of precision and trueness, whereas "trueness" indicates the degree of similarity between an impression and the actual situation—in this context, the patient's clinical condition. By contrast, "precision" refers to whether images obtained from repeated impressions or scans are highly consistent with one another; in other words, it determines the level of detail with which the scanner is capable of capturing such images (6).

The present article aims to conduct a literature review comparing the precision of digital interocclusal records with that of analog methods. The purpose is to provide updated evidence enabling clinicians to understand the fidelity of different protocols, thereby optimizing occlusal analysis and selecting the most appropriate technique for each specific case.

DENTAL WORKFLOW: DIGITAL AND ANALOG

According to recent literature, several methods are available for obtaining interocclusal records. In this regard, Díaz et al. (7) describe both digital and analog dental workflows for obtaining interocclusal records and for model mounting and articulation, based on the following classification:

Analog method

This method consists of: i) impression taking using conventional materials (e.g., alginate, silicone, etc.); ii) pouring of impressions with dental stone; iii) conventional interocclusal recording; iv) mounting of the maxillary model using a facebow record and interocclusal record; v) mounting of the mandibular model; and vi) manual articulation (Figures 1 and 2).

Indirect digital method

This method is performed as follows: i) impression taking using conventional materials (e.g., alginate, silicone, etc.); ii) pouring of impressions with dental stone; iii) conventional interocclusal recording; iv) indirect scanning (using a desktop/extraoral scanner) of the models obtained from the impressions and the interocclusal records; v) mounting using digital techniques; vi) transfer of files to CAD design software; and vii) virtual articulation of models (Figure 3).

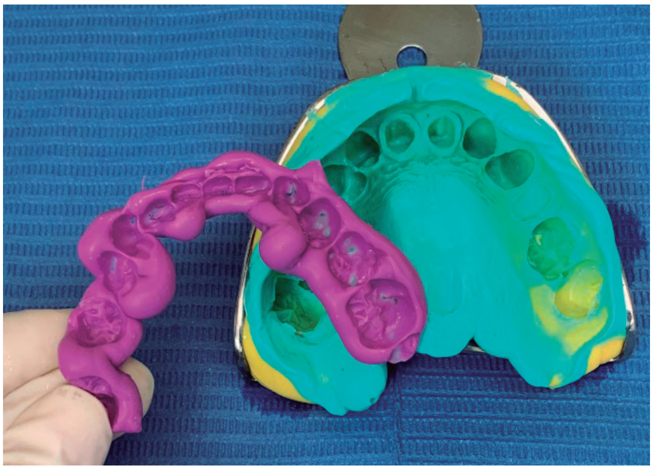

Figure 1. Interocclusal record and analog polyvinyl siloxane (PVS) impression.

Figure 2. Mounting on a semi-adjustable articulator performed using an analog interocclusal record.

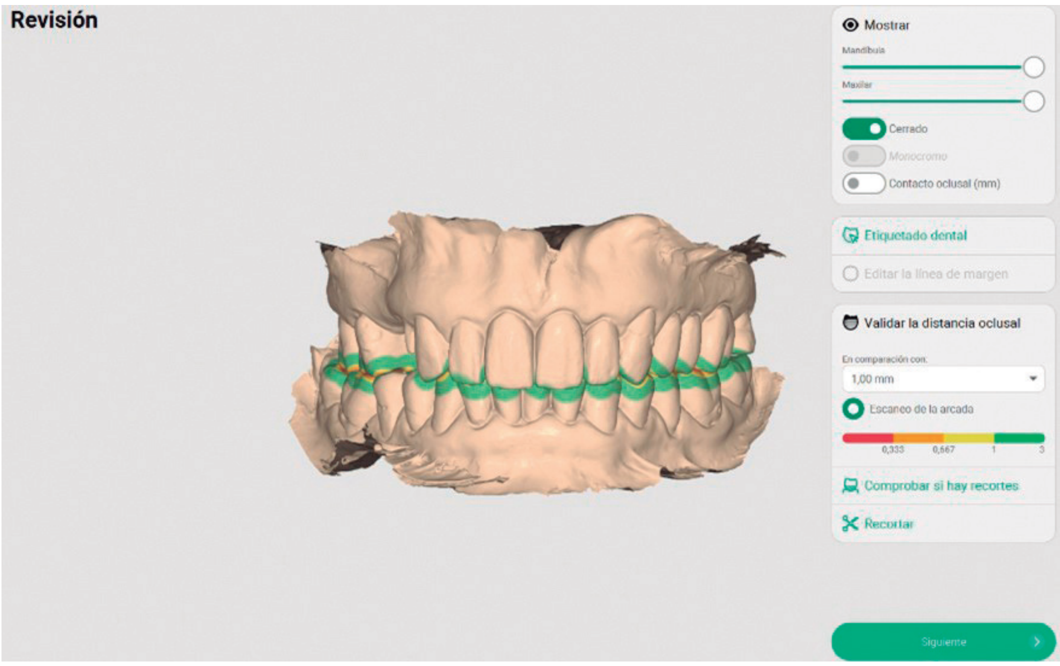

Figure 3. Assessment of interocclusal distance using the Sirios scanner software (Straumann Group).

Direct digital method

This method comprises: i) intraoral scanning of the jaws using an intraoral scanner; ii) interocclusal recording using an intraoral scanner; iii) optionally, auxiliary tools such as a scanner or a virtual facebow, among others, may be used; iv) mounting using digital techniques; v) optionally, additional tools may be incorporated (adjuncts such as cone-beam computed tomography, mandibular movement-tracking systems, etc.); vi) transfer of files to CAD design software; and vii) virtual articulation of models (Figure 4).

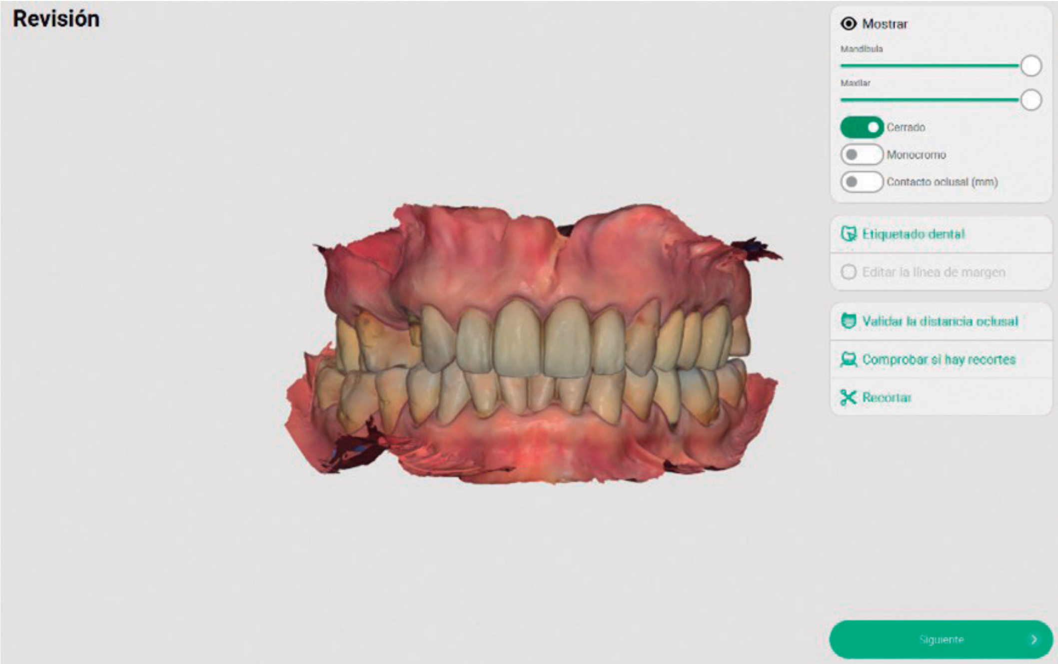

Figure 4. Visualization of the intraoral scan performed using the Sirios scanner (Straumann Group).

ANALOG METHOD

Materials for interocclusal record acquisition

As for the analog method, various materials for obtaining interocclusal records have emerged over time, including alginate, impression plaster, zinc oxide–eugenol paste, waxes, elastomers, and acrylic resin, among others, each with distinct properties. However, it is well established that material precision is an essential factor that may influence the outcome of the record and, consequently, model mounting. To achieve favorable outcomes, ideal properties or requirements for these materials have been described. One of these is biocompatibility, defined as the absence of adverse reactions in patient tissues. Materials should also be easy to manipulate, providing an adequate working time for the clinician while simultaneously allowing verification of whether the record has been properly obtained without distortion. Additional desirable properties include good dimensional stability, precise reproduction of details, and the absence of displacement of oral tissues. Materials should not interfere with mandibular movements, particularly mandibular closure; in other words, they should have low initial viscosity. They should also allow passive seating of the models. Some highly reproducible or excessively rigid materials occasionally prevent proper seating and adaptation of models, thereby requiring the application of force. In the same way, compressible materials (e.g., addition silicones or polyvinyl siloxane [PVS]) may lead to inaccurate mounting (1).

The principal advantage of obtaining interocclusal records through the analog method is that, during manual articulation of study models, maximum intercuspation can be established rapidly and accurately through tactile feedback. In the digital method, this process is more challenging because, without tactile feedback, models are articulated visually or according to the program's specifications. Currently, many visualization software programs lack collision restrictions, allowing 3D models to continue moving even after contact has been established; this may generate mounting inaccuracies. Concerning the disadvantages of the analog method, these are primarily related to the properties of dental materials, which are susceptible to degradation or dimensional changes—also dependent on proper operator handling—material fracture, need for physical storage space, loss, processing time, limited diagnostic versatility, among others (8).

Registration waxes

Waxes are thermoplastic materials widely accepted and used due to their ease of manipulation and low cost. They provide adequate working time and, to a certain extent, allow corrections. However, they have several disadvantages. Many studies indicate that, because wax is a soft and fragile material, it is highly inaccurate due to its thermoplastic nature and dimensional instability, associated with a high coefficient of thermal expansion, which makes it highly susceptible to distortion under elevated temperatures. At the same time, it may offer resistance to mandibular closure, often preventing the acquisition of an adequate interocclusal record (9). Dwivedi et al. (10) reported that model mounting using registration materials exhibits discrepancies along all three axes, which increase when records are transferred to gypsum models. Their study demonstrated that bite registration wax was the least precise material and exhibited lower dimensional stability compared with PVS and polyester.

Zinc oxide–eugenol paste

This material is supplied as a two-tube system: one containing zinc oxide (referred to as the "base") and the other containing the "accelerator." Among its advantages, it is easy to manipulate and store, rigid, and reliable. Additionally, it demonstrates minimal dimensional instability, showing slight contraction of less than 0.1% after 30 minutes of mixing. Another advantage is that it adheres to the impression tray without requiring an adhesive agent, presents minimal resistance to closure, and does not require a separating medium for pouring. Nevertheless, disadvantages include its lack of reusability and rigidity, which makes it highly brittle. Excess material must therefore be trimmed carefully to ensure proper seating and adaptation of models during articulation (8,11).

Acrylic resin

Acrylic resin is a rigid material with excellent precision and accuracy for detail reproduction and is commonly used for fabricating individualized stops during centric relation recording. Its disadvantages include excessive rigidity, which may hinder proper model seating. At the same time, it has been reported to exhibit some degree of dimensional instability due to the acrylic content of its components, predisposing it to low levels of polymerization shrinkage (9).

Silicones

Silicones are considered among the best materials for impression making and interocclusal recording, and they function through chemical activation to initiate polymerization. They are commercially available in different forms (depending on brand and consistency), including bottles, tubes, and automixing cartridge dispense guns, among others (11).

Two types of silicones exist based on composition and polymerization mechanism. The main difference lies in the formation of by-products (alcohol) during polymerization of condensation silicones, which does not occur with addition silicones, making the latter more dimensionally stable.

Condensation silicones, also referred to as polysiloxanes, offer advantages such as affordability, good elastic recovery, accurate detail reproduction, and pleasant taste and odor. However, they are dimensionally unstable when undergoing moderate to high contraction (0.2–1% during the first 24 hours), exhibit low to moderate tear resistance, and are highly hydrophobic (11). Conversely, addition silicones, also known as polyvinyl siloxane (PVS), have excellent detail reproduction, high dimensional stability—demonstrating the lowest contraction values among elastomers (0.01–0.2% at 24 hours)—excellent elastic recovery, good precision, and wear resistance. They are also available in automixing syringe systems, which facilitate manipulation in appropriate proportions and reduce bubble formation. Disadvantages of PVS include its hydrophobic nature, high rigidity, and relatively high cost compared with other materials. In addition, latex particles may interfere with polymerization, so they must be mixed with alternative gloves such as nitrile. Although alcohol by-products are not generated, hydrogen ions frequently form; therefore, according to some manufacturers, pouring should be performed one hour after impression taking (11).

In a study, Sweeney et al. (8) indicated that PVS was the most suitable recording material for articulating digital models in the indirect digital method. Since no universal standard exists for this material type, properties vary in composition, efficiency, and structural characteristics depending on the manufacturer. Certain PVS materials are even available in scannable versions, containing higher levels of titanium dioxide to enhance reflectivity and meet optical scanning requirements (11).

DIGITAL METHODS

Procedures for obtaining digital interocclusal records

With regard to digital workflows for obtaining interocclusal records, several associated advantages and disadvantages have been reported. Queiroz et al. (12) highlighted patient comfort—particularly with the direct digital method—as one of the principal advantages of digital workflows, since dental materials no longer need to be introduced into the oral cavity, which often causes discomfort. This translates into reduced material expenditure and decreased generation of biohazardous waste within the dental office. In addition, the need for physical storage of study models is eliminated, workflow efficiency is increased, working time is reduced, and collaboration between the dentist and dental technician is strengthened through enhanced communication. Another important advantage is that digital software incorporates various tools that facilitate occlusal analysis and other aspects during scanning, which is highly beneficial. For example, these programs allow clinicians to assess occlusal contact intensity, analyze interocclusal space, and perform virtual wax-ups to visualize treatment outcomes, among other applications.

Conversely, disadvantages include the high cost of equipment, the need for ongoing software training—which consequently involves a learning curve—and scanner limitations in detecting deep finish lines, among other shortcomings (12). Another limitation associated with digital workflows is the phenomenon known as "interocclusal perforation" or "mesh interpenetration." This refers to the intersection of surfaces or meshes between scans of opposing arches after alignment of maxillary and mandibular scans, a phenomenon that does not occur in physical models and represents a limitation of computer-aided geometric design. In the study by Beck et al. (13), a greater number of perforations was found in scans performed with intraoral scanners compared with laboratory scanners. This may result in the fabrication of restorations in infraocclusion, compromising clinical accuracy and acceptability. The authors suggest that this issue may be related to the "tilting effect," arising from mesh-construction errors during intraoral scanning that affect alignment and distort occlusal contacts within the record.

The acquisition of accurate interocclusal records is of critical importance in oral rehabilitation. For digital records, both intraoral scanners (used directly in the clinical setting) and extraoral scanners may be employed. Various factors influencing record accuracy when using intraoral scanners have been reported in the literature, including the scanning system, extent of the scanned area, interocclusal space, edentulous spaces, characteristics of the interocclusal record, tooth mobility, and patient- or operator-related factors (e.g., skill level, patient cooperation, etc.) (14).

In the direct digital method, the intraoral scanner is positioned within the patient's oral cavity, and oscillatory movements are performed—ideally according to the manufacturer's instructions—while scanning all tooth surfaces, one jaw at a time. Subsequently, for the intermaxillary record, the buccal surfaces of the maxillary and mandibular teeth are scanned in a predetermined position until the scanning software aligns and merges the previously acquired arch scans, thereby articulating the virtual models. By contrast, the indirect digital method combines analog and digital workflows. Initially, impressions and the intermaxillary record are obtained conventionally. These impressions or the resulting poured models, together with the interocclusal record, are subsequently digitized using an extraoral scanner (also referred to as "laboratory scanner" or "desktop scanner") (15).

Nowadays, literature reflects an ongoing discussion regarding which scanning technique or sequence should be followed for interocclusal record acquisition, depending on the clinical case, with differing viewpoints reported. Mei et al. (16) compared the precision of different scanning strategies for virtual interocclusal records, emphasizing that scanning protocols may influence the alignment of virtual models. Their findings demonstrated improved precision when records were obtained bilaterally at the posterior level. At the same time, they did not recommend digital interocclusal record acquisition in patients presenting absence of three or more posterior teeth, extensive edentulous spans, or extensive unilateral or bilateral distal extension spaces, indicating that these conditions negatively affect record precision. These results were consistent with the conclusions of the systematic review conducted by Revilla-León et al. (14), who reported that, to maximize the accuracy of an interocclusal record in maximum intercuspation during full-arch intraoral scanning, a bilateral and anterior record including two teeth, or a bilateral posterior record including at least four teeth, is required. For half-arch scanning, they recommended a posterior occlusal scan including at least four teeth to optimize interocclusal record accuracy.

DISCUSSION

Recent scientific literature has debated the accuracy of both methods for obtaining interocclusal records. Morsy et al. (17) conducted a comparative study evaluating the accuracy of conventional interocclusal records (using addition silicones) versus digital records (obtained using an intraoral scanner). They found that although all records demonstrated acceptable accuracy, the values obtained in the digital group were significantly more precise than those of the conventional records. They indicated that these results were attributable to the fact that, when materials such as polyvinyl siloxane (PVS) are used for mounting gypsum models, inaccuracies in articulation may occur due to the dimensional changes inherent to both silicone and gypsum, inadequate seating of models within the record, and silicone compressibility. Similarly, when silicone records are scanned as part of the indirect digital workflow, slippage and discrepancies may arise during the scanning process. Based on these findings, the authors concluded that digitally acquired records exhibited superior accuracy compared with conventionally obtained records.

Similarly, in a study published by Ries et al. (18), a three-dimensional analysis of accuracy comparing conventional and fully digital methods was conducted.

Their findings demonstrated that fully digital workflows exhibited greater accuracy compared with the digitization of conventional records. Furthermore, they reported that the scannable registration material used in the indirect digital method also produced acceptable results. On the other hand, Iwauchi et al. (15) conducted a study comparing the accuracy of records obtained using an intraoral scanner with those acquired through conventional methods employing addition silicone and dental stone. Their results demonstrated that digital scanning methods using intraoral scanners achieved greater accuracy than conventional techniques, both for full-arch and quadrant records. These authors emphasized that enhanced accuracy has been documented, particularly in limited-span regions, highlighting that digital techniques eliminate the need for mounting models in an articulator, thereby avoiding the dimensional errors inherent to conventional dental materials.

Numerous studies have demonstrated the substantial capability of intraoral scanners to capture information and three-dimensional images and to obtain accurate records without the inherent limitations associated with conventional dental materials. Digital records have been shown to provide greater accuracy with respect to spatial relationships and occlusal fit, thereby reducing the need for future adjustments during prosthetic rehabilitation. Nevertheless, there are limitations to digital records associated with differences in scanning technologies and virtual articulation algorithms, which can lead to distortions in the interocclusal record. In a systematic review, Nagri et al. (19) concluded that intraoral scanners and digital techniques provide greater accuracy than conventional records obtained using silicone and gypsum. They also indicated that records are more accurate for quadrant scans compared with full-arch scans, and that a fully digital workflow is more accurate than the digitization of conventionally obtained records. Their article further noted that, although intraoral scanning systems may generate structural superimpositions capable of producing distortions, they do not create false occlusal contacts; rather, they tend to omit occlusal contacts. This issue should be considered by clinicians when selecting the intraoral scanner to be used in order to minimize potential discrepancies.

Despite the relevant information identified, limitations within the reviewed literature should be acknowledged. Currently, the market offers a wide variety of intraoral and desktop scanner brands and models, each possessing distinct properties and scanning technologies. In addition, each study employed a different methodology for evaluating the accuracy of interocclusal records, which may have contributed to variations among the reported findings. Future studies are recommended to evaluate strategies for improving the accuracy of digital interocclusal records, including variables such as scanning time, scanning sequence, and scanning technique.

CONCLUSIONS

According to the literature review conducted, several authors agree that digital methods and the digitization of interocclusal records demonstrate greater accuracy than conventionally obtained records. As previously mentioned, multiple variables influence the accuracy of these records. Regarding digital techniques, influential factors include scanning strategy, extent of the scanned area, scanning technology, and scanner type, among others. Conversely, conventional techniques are influenced by variables associated with the characteristics and inherent properties of the material used. Patient-related factors must also be considered, including the degree of cooperation and the ability to position the mandible correctly in the desired recording position, as well as clinician-related factors such as the dentist's skill in obtaining the record and properly handling the material or scanner employed. It is important for the dentist to individually assess each patient and determine which technique and equipment/materials are most appropriate. This approach aims to obtain an accurate interocclusal record, enabling a correct diagnosis, appropriate treatment planning, and ultimately the successful rehabilitation of the patient.

Conflict of interest:
The authors declare no conflict of interest.

Funding:
Self-funded.

Authorship contribution:
VLN: conceptualization, research, methodology, visualization, writing of the original draft, writing - review & editing. **JABR, EADS:** conceptualization, research, supervision, visualization, writing of the original draft, writing - review & editing.

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