Digital Management of Functional Occlusion Utilizing Digital Pressure-Sensing Registration

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Abstract

The primary goal in the treatment of patients with full-arch restorations is to ensure a comfortable, functional occlusion with a structurally sound restorative prosthesis. While prosthetic failure is a multifactorial issue, occlusal overload is an important potential contributing factor. Until recently, intraoral occlusal measurement has been confined to the use of articulation paper. However, occlusal measurement technologies have now advanced to include the use of digital occlusal-pressure articulation, which allows the recording of masticatory forces over a designated time period. OccluSense® (Bausch; Köln, Germany), a wireless digital device for occlusal pressure measurement, combines traditional carbon articulation with digital pressure-sensing registration to enable clinicians to view occlusal pressure patterns and evaluate premature or hyperocclusal contacts for potential reduction. This article provides a case study comparing traditional articulation versus digital occlusal-pressure articulation using the OccluSense digital device, both of which were used in a patient who required full-mouth rehabilitation.

Introduction

The use of full-arch implant-supported fixed restorations in clinical practice has increased dramatically over the past several decades. At the same time, patients today have a greater awareness of the various full-arch implant options that are available, as well as the potential financing and payment plans for treatment, and thus are better empowered to enhance their quality of life through the improved function and esthetics of restored dentition. As a result, dental occlusion has once again become a highly relevant and important topic in dentistry, as ensuring a functional occlusion is central to successful full-arch rehabilitations with a structurally sound prosthesis.

Role of Occlusion in Prosthetic Failure

For decades, conventional crown and bridge dentistry for both natural teeth and dental implants has been achieved with ceramo-metal restorations. While metal has always served as a reliable substructure that is highly resistant to fracture, the secondary ceramic layers have been prone to chipping or fracturing as a result of misdirected or excessive occlusal forces. Improvements in ceramic materials (eg, zirconia) and production capabilities (eg, 3D printing, milling units) have been helpful in enabling laboratories and dental technicians to fabricate stronger, longer-lasting solutions. In addition, improved synergies between ancillary technologies such as intraoral scanning, photogrammetry, and virtual articulation have reduced the production time and increased the accuracy of ceramo-metal restorations. However, even with stronger and more precise ceramic materials, prosthetic fracture and implant failure due to occlusal overload remain a valid concern.

Prosthetic failure is a multifactorial problem that goes beyond issues of ceramic strength. Factors that contribute to potential restorative failure are increased stress due to lack of appreciation of the proper vertical dimension of occlusion (VDO); reduced height and thickness of material; poor reduction of substructures; increased cantilever or pontic lengths due to poor anterior-posterior spread (A-P spread); and an unbalanced occlusion. An occlusal high spot on a screw-retained prosthetic in the location of a titanium base (Ti-base) often results in fracture propagation, as it is a point of weakness (Figure 1).

Advancements in Occlusal Measurement Technologies

Dental occlusion has been studied for decades, resulting in various schools of thought regarding optimal treatment. While the 3-dimensional (3D) relationship of the jaws is clearly defined by the VDO, horizontal centric relation, and envelope of function, theories regarding occlusion may conflict as to whether occlusal function is tooth-borne, neuromuscular, skeletal, static, dynamic, based on centric relation, or based on centric occlusion. Regardless of differing opinions, the common goal in the treatment of patients with full-arch restorations is to ensure a comfortable, functional occlusion with a structurally sound restorative prosthesis, which will ultimately result in improved patient satisfaction.

While dental technology has progressed dramatically over the past several years, until recently traditional measurements of occlusal contacts and balance have undergone very little change. Although extraoral articulation is extremely valuable and has been enhanced through the use of digital technology, conventional measurements of intraoral occlusion have remained limited to the use of articulation paper (Figure 2), the clinician's observations of carbon paper markings, and the patient's awareness of pressure. Unfortunately, patient perception becomes increasingly difficult to utilize when proprioception is absent or diminished, as is the case with patients who have dental implants. In patients with full-arch and full-mouth implant rehabilitation, a broader awareness of the patient

Fig 1.


Fig 2.

Figure 1. A fractured full-arch zirconia restoration. Despite recent improvements in the strength and accuracy of ceramo-metal materials, modern dental materials remain capable of fracture. Note the location of the fracture adjacent to the titanium cylinder, a susceptible area where the material can be thin. **Figure 2.** Various types of articulating paper (Bausch; Köln, Germany), ranging from 40 microns to 200 microns in thickness. Most articulating papers are available in strips designed to analyze one side of the mouth, while others are horseshoe-shaped to analyze the entire mouth

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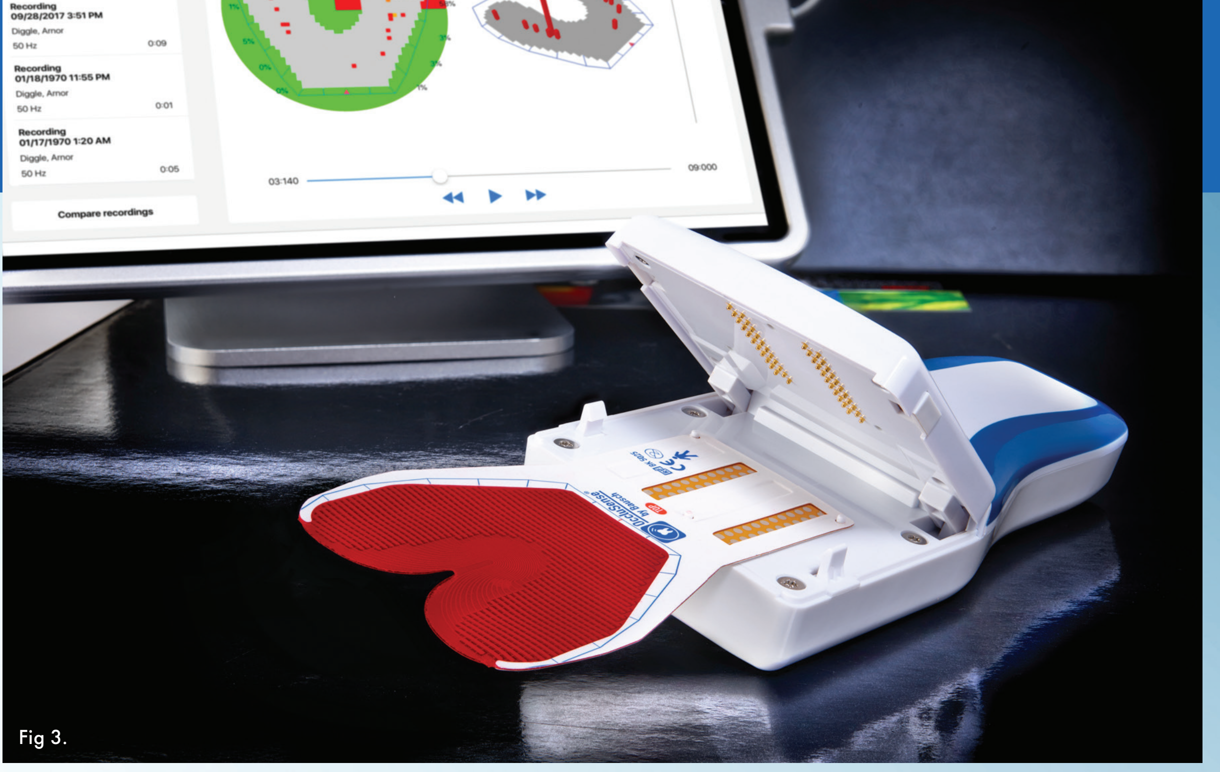

Fig 3.

Figure 3. OccluSense® device (Bausch; Köln, Germany), which combines traditional carbon articulation with digital pressure-sensing registration, allowing the recording of masticatory forces over a designated time period. The masticatory pressure is recorded digitally with more than 1000 points of contact in 256 pressure levels and is transmitted wirelessly to an iPad, where the data can be read in 2- and 3-dimensional graphics.

is required, with muscular and skeletal sensations utilized to convey potential occlusal imbalances that are otherwise often unnoticed.

Initially, intraoral occlusal measurement technologies could be used only to measure static pressure points, through the use of gauges. Over the past few years, however, these technologies have advanced to include digital devices that can capture pressure and movement over time, thus greatly enhancing diagnostic competencies. By incorporating these innovative technologies with traditional methods, clinicians can achieve an ideal measurable outcome, which in turn will improve the functionality and resiliency of both temporary and final restorative materials.

An innovative wireless device called OccluSense® (Bausch; Köln, Germany) combines traditional carbon articulation with digital pressure-sensing registration, allowing the recording of masticatory forces over a designated time period (Figure 3). A disposable, 60-micron thin, red, carbon-lined pressure sensor is inserted into the device and applied in the manner of traditional articulation foil. The masticatory pressure is recorded digitally with more than 1000 points of contact in 256 pressure levels and is transmitted wirelessly to an iPad. The device has the capability of capturing both static and dynamic occlusion. The captured data can then be viewed as 2D and 3D graphics, with up to 150 images recorded per second. The recordings can be measured over a selected period of time. In "live" mode, the duration is not limited, while in "recording" mode, a set time is needed to conclude the data collection. The recordings can collect temporal progression data, from the initial contact to the final intercuspal position in maximum intercuspation. Once the transfer is completed, the clinician can utilize the OccluSense software to view the occlusal pressure patterns and evaluate premature or hyperocclusal contacts for potential reduction. Multiple occlusal sessions can be recorded for the same patient until a desired occlusal result is achieved.

Indications for digital occlusal-pressure articulation include, but are not limited to, pre- and post-orthodontic movements, temporomandibular joint dysfunction (TMD), and restorative dentistry procedures ranging from simple single-tooth restoration to full-mouth therapy. The authors recommend that the device should be used in conjunction with traditional methods to provide the highest level of accuracy in the measurement of functional occlusal relationships.

The following case presentation compares the use of traditional articulation versus digital occlusal-pressure articulation using the OccluSense digital device, both of which were used in the same patient to aid in the recording of premature and eccentric contacts and to decipher occlusal patterns for the facilitation of accurate full-mouth rehabilitation.

Case Presentation

A 74-year-old woman with a noncontributory medical history presented for a rehabilitation consultation. A thorough examination was performed, including but not limited to intraoral examination, digital radiography, cone-beam computerized tomography (CBCT), intraoral scanning of arches, scanning of occlusion, and extraoral photography. The patient was aware of failing maxillary terminal dentition and pre-existing dental implants but was not aware of failing full-arch mandibular implants (Figures 4 and 5).

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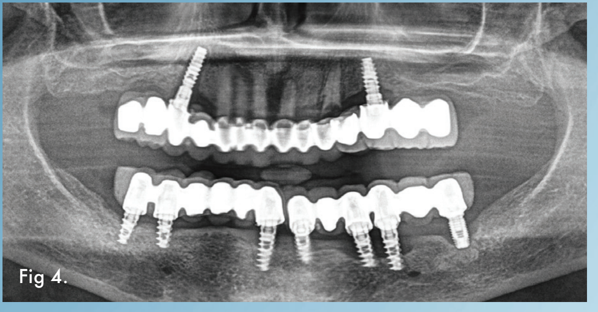


Figure 4. Preoperative panoramic radiograph of the patient. On the failing maxillary arch, implant No. 4 is not integrated, implant No. 13 has crestal bone loss, and natural teeth have gross decay and infection. On the failing mandibular arch, many of the implants demonstrate significant bone loss. **Figure 5.** Preoperative photograph showing failing maxillary and mandibular full-arch prostheses. **Figure 6.** CHROME™ GuidedSMILE (ROE Dental Laboratory, Independence, Ohio) fully guided surgical guide, with mechanisms for a stackable bone-supported framework. Based on digital planning of the case, this surgical guide was fabricated for the extraction of existing dentition/implants as well as for placement of final implants. **Figure 7.** Immediate loading of the maxillary dental implants utilizing the CHROME™ GuidedSMILE (ROE Dental Laboratory, Independence, Ohio) stackable system. The system helped create a prefabricated provisional prosthesis that was luted intraorally to titanium cylinders seated on multi-unit abutments.

The patient was presented with a full-mouth treatment plan that involved a staged approach. Initial treatment of the maxillary arch was prioritized, owing to the presence of two severely failing implants, tooth decay, mobility, discomfort, and infection. The mandibular arch, although temporarily stable, would require implant removal and rehabilitation after the maxillary arch was stabilized with a transitional prosthetic. The treatment plan for the maxillary arch consisted of virtual extractions, a preplanned prosthetic position maintaining the patient's VDO, followed by virtual implant osteotomies and implant placement with the use of the CHROME™ GuidedSMILE (ROE Dental Laboratory, Independence, Ohio) fully guided surgical approach.

A metallic 3D surgical guide with Chrome-locking mechanisms for a stackable bone-supported framework was fabricated with a premilled temporary nano-ceramic prosthetic (Figure 6). The guided surgical intervention was uneventful, with the accurate placement of seven dental implants (AnyRidge®; MegaGen; Englewood Cliffs, New Jersey) placed according to the CBCT plan and metal drill guided. All extraction sites and defects were then filled with autogenous dentin grafting (Smart Dentin Grinder™; KometaBio Inc.; Fort Lee, New Jersey) in conjunction with guided bone regeneration techniques. Using torque measurements combined with objective implant stability quotient (ISQ) scale (Osstell; Göteborg, Sweden) measurements, it was decided to immediately load the dental implants using multi-unit abutments to accurately seat and then lute intraorally the titanium cylinders to the prefabricated prosthesis, which was accomplished through the CHROME GuidedSMILE stackable system (Figure 7). Postoperatively, the patient was instructed to maintain a soft diet until it had been determined that implant integration had been achieved. Proper postoperative instructions and care were delivered.

After an uneventful healing period of 4 months, the patient returned for assessment of healing and evaluation. Treatment of the lower arch was discussed; however, she was hesitant to begin treatment at that time because of new financial constraints that had not been a concern at the time of the original treatment planning. The patient preferred to have the rehabilitation of the maxillary arch completed first and to return later for mandibular therapy, as her mandibular arch was currently stable. The iJIG™ protocol (ROE Dental Laboratory) was utilized to maximize record accuracy. Intraoral scanning was then performed to digitally capture the temporary maxillary prosthesis with special scanning analogs attached. The laboratory uses the scan and produces a "sectioned" resin arch form connected to multi-unit copings for pick-up and verification.

The sections were then secured intra-orally to the multi-unit abutments, and the jig was luted together with a resin-pattern powder-liquid material until set. Polyvinyl siloxane impression material was flowed under and around the prosthesis intraorally to capture the intaglio surface and postsurgery soft tissue discrepancies. A bite registration was recorded intraorally and sent back to the laboratory for mounting (Figure 8). Once digitization was completed, CAD/CAM software was utilized to design a virtual arch, which was then exported for 3D printing. Next, a full-arch resin try-in was seated onto the multi-unit abutments to verify fit, soft tissue adaptation, occlusion, phonetics, and esthetics (Figure 9). The occlusion and all excursive movements were captured by traditional articulation with carbon paper and foil and adjusted. A final monolithic zirconia prosthetic was milled, sintered, stained, and delivered (Figure 10). Inaccuracies in adjustments of the printed try-in, possibly caused by limitations in conventional articulation methods, necessitated several visits for occlusal adjustments over the subsequent weeks until the patient's comfort and articulation could be confirmed.

After 4 years, the patient returned for follow-up and reported discomfort with the mandibular arch implants. The mandibular arch was re-evaluated, and treatment was planned for rehabilitation. Because several years had passed, significant bone loss had occurred around the failing implants. After implant removal, bone reduction was necessary to create a wider, level plane for the new implant-supported restoration. Thorough 3D planning was used to confirm sites for immediate implants, followed by an immediate loaded prefabricated prosthesis utilizing the improved CHROME GuidedSMILE protocol with C2F (convert to final) small hole technology. Because the patient's finances

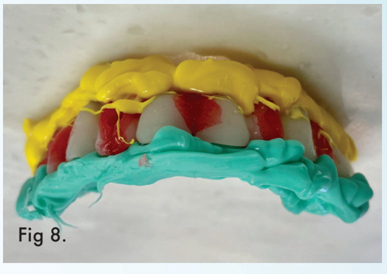


Fig 8.


Fig 9.


Fig 10.


Fig 11.

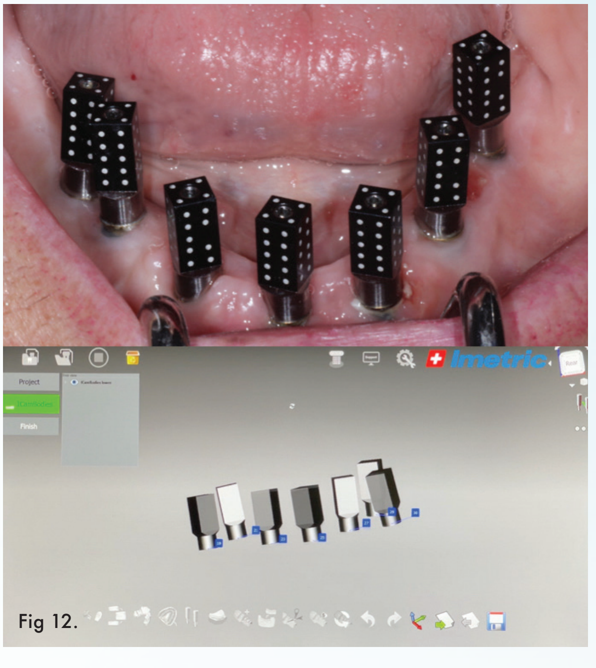


Fig 12.

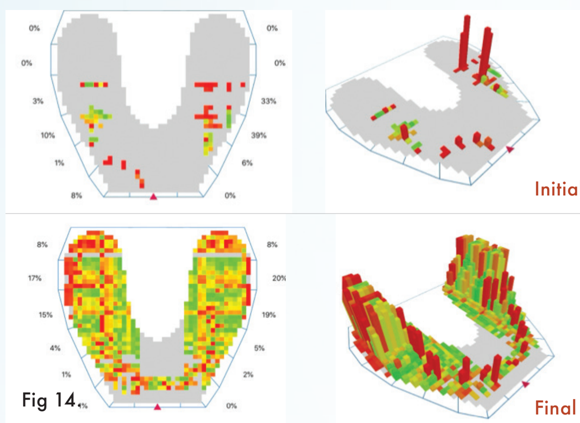
Figure 8. The iJIG™ protocol (ROE Dental Dental Laboratory, Independence, Ohio) was used to create a final maxillary prosthesis. The part of the protocol shown here involved luting together a sectioned resin arch, flowing polyvinyl siloxane underneath it to capture the soft tissue form, and flowing Blu Mousse over it to capture the occlusion. **Figure 9.** The next step in the iJIG™ protocol (ROE Dental Dental Laboratory, Independence, Ohio), at which a full-arch printed resin try-in was seated onto multi-unit abutments to verify fit, soft tissue adaptation, occlusion, phonetics, and esthetics. The resin try-in was fabricated using the information from the luted, sectioned resin arch that had been produced at the previous appointment. The occlusion and all excursive movements were captured by traditional articulation with carbon paper and foil and were adjusted prior to final prosthesis fabrication. **Figure 10.** A final monolithic zirconia prosthetic was milled, sintered, stained, and delivered. **Figure 11.** Immediately loaded temporary prosthesis for the mandibular arch, created through the improved CHROME™ GuidedSMILE (ROE Dental Laboratory, Independence, Ohio) protocol with C2F (convert to final) small hole technology. Note the difference in size of the holes in this improved prefabricated provisional prosthesis versus the maxillary one. **Figure 12.** To achieve data collection using extraoral photogrammetry iCAM 4D (iMetric4D; Courgenay, Switzerland) scannable analogs that resemble dominoes are placed in the patient's mouth and scanned in addition to traditional intraoral scanning of the patient's arch and temporary prosthesis. This accurate scanning technique allows a final zirconia prosthesis to be delivered without additional verification jigs or printed try-ins.

were still an issue, we invited her to our Advanced Implant Education (AIE) training facility in Mexico to be treated, thus providing the patient with an affordable surgical and provisionalization treatment option. The surgery was uneventful, with the placement of six implants (AnyRidge, MegaGen). Torque and ISQ values were recorded, and immediate temporization of the implants was deemed prudent. Multi-unit abutments were torqued in place, and the C2F conversion process was executed and delivered (Figure 11). Postoperative instructions were reviewed, which included a soft diet as previously discussed.

The patient returned to our office in New York. Using our newly acquired OccluSense occlusal-pressure measuring system, adjustments were made. Static and dynamic movements were captured on the iPad, evaluated, and adjusted. Upon completion of the adjustments, the patient reported immediate improvement, with a comfortable, functional occlusion. No other visits were required for occlusal adjustments of the provisional. Approximately 3 months later, the patient was re-evaluated. It was determined that implant integration, soft tissue stability, as well as a stable functional occlusion had been achieved. The positive outcome confirmed the plan for the final restorative phase for the mandibular arch to utilize a full-arch monolithic zirconia prosthetic. Data collection was accomplished using intraoral scanning of the arch and temporary prosthetic with scannable analogs (iJig, ROE Dental Laboratories), along with extraoral photogrammetry (iCAM 4D, iMetric4D, Courgenay, Switzerland). Without the need for any further verification jigs or printed try-ins, a final zirconia prosthetic was milled and delivered (Figure 12). The prosthetic was inserted without Ti-bases (Figure 13). Removing Ti-bases from the structure allowed for increased thickness of zirconia without cement for Ti-base bonding. These benefits reduce bonding complications and provide increased strength for the final prosthetic. Specially designed fixation screws (Rosen screws) were used to avoid Ti-bases, as standard multi-unit abutment screws would not be applicable without Ti-base caps. Occlusal measurements were then obtained with the OccluSense occlusal pressure measuring system, and minor adjustments were made swiftly with the aid of the iPad recordings (Figure 14). New recordings were monitored and confirmed at all subsequent follow-up hygiene visits. Follow-up radiographs depicted full-seated restorations with stable bone levels (Figure 15)

Discussion

The unique needs of this particular patient, who required dual-arch treatment, allowed for the comparison of the two articulation methods: digital dental articulation versus traditional articulation. The patient reported that, although the surgical aspects of treatment were similar in both arches, the mandibular restorative process was vastly simpler and significantly more comfortable from the outset of temporization to delivery of the final prosthesis. Anecdotally, the difference in the two experiences can be attributed to improvement in intraoral scanning devices, the use of photogrammetry, and the digital occlusal-pressure articulating system for the mandibular restoration, which were not available at the time of the initial treatment 4 years earlier.



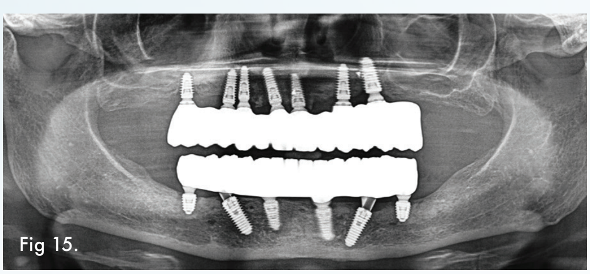


Figure 13. Final mandibular zirconia prosthesis. The prosthesis was inserted without Ti-bases, which allowed for increased thickness of zirconia to increase strength for the final prosthesis. **Figure 14.** Data collected from the OccluSense® pressure measuring system (Bausch; Köln, Germany), showing an initial unbalanced bite, with 72% of the occlusal force concentrated around the lower left posterior region. Following some occlusal adjustments, the patient's occlusion was correctly balanced and evenly distributed. **Figure 15.** Follow-up panoramic radiograph of completed treatment with final maxillary and mandibular zirconia prostheses.

The ability to capture all phases of the static and dynamic occlusal and excursive movements in real time significantly reduced chairtime for this patient while providing the clinician with a predictable post-restorative treatment.

Conclusion

While this case demonstrates the usefulness of the OccluSense pressure measuring system for full-mouth implant-supported restorations, in the dental practice of the authors the device also plays an integral role in orthodontics, general dentistry, management of TMD, and even treatment with traditional fixed or removable prosthodontics.

Ensuring functional occlusion is central to the treatment of patients requiring full-arch restorations and to the longevity of the prosthesis. When used in conjunction with traditional articulation, digital occlusal-pressure articulation can provide high levels of accuracy in the measurement of functional occlusion. Using the innovative digital occlusal-pressure measurement system described in this article, both static and dynamic occlusion can be captured to decipher occlusal patterns, which is crucial to facilitating full-arch or full-mouth rehabilitation.

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