The Use of Digital Tools in an Interdisciplinary Approach to Comprehensive Prosthodontic Treatments

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Contemporary dental treatments have to evaluate not only the biological and functional needs of each single case but also the increasing esthetic demand of patients. A patient-centered approach is leading clinicians towards comprehensive treatment planning, and, nowadays, restorative dentistry and prosthodontics are focused on patients’ needs, requests and expectations [1]. Moreover, patients are more and more informed about innovative techniques, materials and operative possibilities because of digital and marketing tools sometimes being rampant but not always of good quality [2]. As a consequence, their expectations and requests are becoming more and more stressful for clinical operators. Moreover, the revisionalization of final results, mainly from an esthetic point of view, has become a key point of the crucial and complex process of treatment planning [1].

From an operative standpoint, we are living in the minimal intervention dentistry era, a really viable approach in terms of saving costs during operations, but it occasionally tends to be abused for fashion trends. Furthermore, we are experiencing a period of significative marketing and technological innovations that allow us to modify clinical approaches by means of increasingly more conservative procedures and novel restorative materials [3,4].

In order to make patients clearly understand the goals and possibilities of a treatment plan and to properly check the different steps of a comprehensive rehabilitation program, the communication of the dental team (referring to general practitioners and specialists (like periodontists, orthodontists and prosthodontists) and dental technicians) plays a pivotal role in achieving optimal functional and esthetic outcomes [5,6].

Undoubtedly, the new digital technologies available in dental practice make the diagnostic and planning processes easier and predictable, since the patients’ information and digital data can be integrated in a single dataset that comprises face scanning, optical impressions made with intra-oral scanners (IOSs) and bone volumes obtained from cone beam computed tomography (CBCT), allowing to work with the so-called “digital patient”. This is particularly useful in complex cases with high esthetic expectations that require orthodontic and periodontal preparatory approaches prior to the restorative finalization [7–9].

The acquisition of 3D images of extra- and intra-oral structures allows us to virtually define the different steps of a treatment plan, to design and fabricate restorations and to monitor the outcomes of different operative procedures. Consequently, a “virtual patient” can be obtained from the superimposition of facial, skeletal and intra-oral imaging, designing a previsualization of the expected esthetic results, which is very useful for instigating discussions among clinicians and for talking over possible modifications with patients before proceeding with real clinical steps [10–12].

Treatment planning for patients requiring pre-prosthetic orthodontics must always begin with an analog diagnostic wax-up or a digital previsualization in order to evaluate...
the potential final results; the orthodontist has to confirm that changes in tooth position can be obtained, and the prosthodontist has to confirm that tooth position is optimal for future restorations, fulfilling the functional and esthetical needs of the case [13,14].

Each clinician enrolled in the treatment has to know the specific stage of intervention, the time needed to fulfill the objectives of treatment and the cost of the provided rehabilitation; all of this information should be explained to the patient before agreeing to proceed with the proposed treatment plan [1,13,14].

It is worth noticing that the specific specialized dental areas (just like orthodontics, periodontics, surgery and prosthodontics) minimally influence the prognosis of a rehabilitation program, while the correct formulation of a treatment plan is certainly the key to the success and longevity of restorations and is affected first by operators’ skills and then by patients’ expectations [15]. As a consequence, clinical success has to be based on correct treatment plans that—thanks to the recent developments offered by digital diagnosis and datasets—have become a complex but trustful process, merging different specific skills into dental teams, allowing patients’ needs to be satisfied with the most appropriate personalized treatments. However, a multidisciplinary approach is not enough. This is because it keeps knowledge from different fields but remains within its own limits, whilst an interdisciplinary approach merges different disciplines into a coordinated and harmonious clinical approach [16]. Such an interdisciplinary treatment planning has been significantly enhanced by digital tools, particularly regarding the diagnostic and designing processes. In fact, the possibility to acquire 2D and 3D images of bone volume, teeth, soft tissues and restorations has significantly improved the communication between a dental team and the control of each clinical step. This has been made possible thanks to a backward approach and a prosthetically guided restorative plan, which starts from the previsualization of the ideal finalization of a case and moves back to each single preparatory clinical step [10–12].

Although nowadays, when the topic of esthetical prosthodontics is talked about, people are used to thinking of trendy and fashionable adhesive restorations, just like ceramic veneers and table-tops, it is worth remembering that the guidelines to achieve satisfactory functional and esthetic results are the same if operators manage patients with tooth-supported, implant-supported and removable appliances. Of course, the classical paradigms regarding precision and biology are the primary considerations for treatment plans, profiting from the best properties innovative restorative materials and updated techniques. Moreover, besides dealing with gingival, peri-implant or mucosal tissues, the conventional principles of prosthodontics have to lead clinicians towards the delivery of precise and biocompatible restorations that could guarantee not only esthetics but also good function and clinical serviceability over time [17].

When it is possible to take advantage of digital tools and different dental skills in a comprehensive interdisciplinary approach, the path for clinical success is achievable and repeatable.

1. The Use of Digital Tools in the Interdisciplinary Restorative Treatment

In the recent 3 years, the number of prosthetic restorations fabricated with a digital workflow has been more than doubled, thanks to the diffusion and reliability of Computer-Aided Design/Computer-Aided Machining (CAD/CAM) systems. The major investments were made by dental laboratories with the purchase of milling units and laboratory scanners, whilst only 9% of dentists bought IOS systems. This is a relatively low percentage that reflects the most recent marketing data, which show that, to date, one-third of dentists has already invested in digital dentistry, one-third declares to be about to do that in the near future whilst the remaining third feels uncomfortable with digital tools. Although this distribution is rapidly changing year by year because of dental manufacturers and laboratories being pushed towards digital workflows, the switch from general practitioners to digital dentistry is significantly conditioned by both age and education [18,19].

Undoubtedly, innovative digital technologies superimposing information obtained from face scanning, CBCT and IOS impressions have made the diagnostic and planning
processes user-friendly and reliable. This has been made possible due to different digital data being able to be merged in a single dataset, resulting in the so-called “digital patient” to be treated virtually before any real operative procedure is carried out, allowing to correct potential clinical drawbacks and show the possible final results to patients [20–22].

The digital workflow of a comprehensive dental treatment can be divided schematically into different clinical steps: data acquisition, previsualization, intervention, impression, design and manufacture.

2. Digital Data Acquisition

In contrast to a conventional analog approach, data acquisition can be performed with digital tools that are comfortable for patients and user-friendly for clinicians, just like digital face bows and articulators. By means of such instruments, it is possible not only to transfer intermaxillary relationships to the dental laboratory but also to analyze and evaluate occlusal parameters and mandibular movements in real time. The numerical values of occlusal determinants are provided by digital face bows, being able to be imported directly in the CAD environment to use a digital articulator in a full-digital workflow or to set a physical analog articulator to be used in a semi-digital workflow. Moreover, the most recent IOS systems have been implemented with the real-time dynamic registration of mandibular movements in order to skip the use of digital face bows and transfer static and dynamic occlusal contacts to CAD software directly from optical impression making [11,12].

Similarly to conventional prosthodontics, on the basis of the complexity of treatment plans, the operator can decide to set the prosthetic project with average values (particularly in simple cases like single restorations) or individual values by scanning analog articulators or directly using digital ones in a partially or fully digital workflow, respectively [11,12].

With regard to extra-oral tissues, pictures of the patient’s face can be easily superimposed to IOS data by means of different systems of reference points; moreover, face scanners offer an optimal quality of surface details with a resolution of about 500 µ and very quick scanning procedures that last about 15 s [5,10–12,20].

Similarly, bone volumes can be easily acquired by means of digital radiology techniques. According to the well-known ALARA (As Low As Reasonably Achievable) statement, a safety principle designed to minimize radiation doses, it is preferable to use CBCT information with low power (20–130 µSv) rather than CT images with high output (∼1100 µSv); although CBCT data are less accurate than CT data, their use was reported to be clinically acceptable, with mean deviations being lower than 0.4 mm [15,21].

3. Digital Previsualization

Besides the advantages being purely related to treatment planning, innovative digital technologies represent a powerful communication tool between individuals in the dental team and with patients as well [5,6,9].

In order to have a clear visual idea of the possible final result, the existing smile should be analyzed three-dimensionally. A patient’s expectations and a clinician’s operative possibilities have to be precisely and successfully communicated; this communication and cooperation process between the patient and the dentist will determine the success or failure of the treatment [5,9,23].

In conventional prosthodontics, the mock-up technique was proposed to fabricate a functional and esthetical smile simulation to be used directly onto the patients’ unprepared teeth [24]. Similarly, virtual smile design systems were conceived to show the prosthetic project to the patient in the digital environment; however, it is worth noticing that limited functional data and no phonetic information can be obtained from such digital simulations [5,9,23].

If used correctly, virtual smile design systems offer several undeniable advantages [5,9,23]:

- Quick simulation of the possible treatment result (before and after comparison).
- User-friendly, time-saving and cheap procedure (software-based planning needing only extra- and intra-oral pictures with no laboratory involvement).
• Improved three-way (operators–dental technician–patient) communication, stimulating discussions within the dental team, involving the patient in the decision-making process and increasing the acceptance rate of the treatment plan.
• Backward approach to the treatment plan (reduced invasiveness, increased predictability, step-to-step interdisciplinary check).
• The digital mock-up can be completed with different approaches [5,9,23]:
  • Self-made by the operator, with simple freehand 2D drawings and/or mirroring tools.
  • Software/template-guided, using specific virtual smile design systems or templates and libraries available on the Internet.
  • IOS-guided, by means of dedicated applications and suites integrated in the software of the most updated IOS systems.

Independently from the chosen digital mock-up approach, the precision and reliability of any virtual previsualization relies on a proper alignment between extra- and intra-oral images; indeed, it was reported that misalignment may lead to discrepancies between facial and dental midlines that do not coincide in 30% of cases [9,23]. Manufacturers and marketing specialists usually focus the operators’ attention on esthetic alignment, probably because it is the most impressive for patients; nonetheless, from the operative standpoint, functional alignment is much more important, allowing to precisely analyze mandibular movements in the CAD environment. In order to simplify the operative procedures and reduce the number of clinical steps, nowadays it is possible to make a one-tool alignment using the most updated IOS systems, which allow to record both extra- and intra-oral tissues and superimpose the previsualization of the virtual smile design [10–12].

As previously reported, poor functional information and no phonetic data can be deduced from such digital simulations; consequently, once the esthetic project has been clearly discussed and accepted, a physical mock-up used as an intra-oral test drive is mandatory to validate the clinical feasibility of the restorative treatment [24].

Digital previsualizations are useful not only to show the potential outcome to patients but also to check the step-by-step procedures over time. Particularly, the virtual smile design plays a pivotal role in long-term interdisciplinary treatments, just like orthodontic therapies that need a restorative finalization to extol both the functional and esthetic results of the rehabilitation. The clin-check used to fabricate orthodontic aligners should be considered a prosthetically guided treatment plan that orients the orthodontist in tooth movements and allows the prosthodontist to assess the achievement of the right functional and biomechanical positions of teeth, enabling to perform the most conservative restorative treatment [7,9,13].

4. Digital Intervention

A proper digital planning preparatory to the fabrication of orthodontic aligners is crucial to preserve sound tissues, making the subsequent prosthetic and restorative steps less invasive, according to the principles of minimal intervention dentistry [7,9,13].

Apart from a harmonious and congruent distribution of teeth within dental arches, the digital planning and the clin-check should take into consideration the room necessary to optimize the shape and volume of final restorations, keeping, for example, some residual space between the front teeth if the case has to be finalized with ceramic veneers or composite restorations; this would prevent the prosthodontist to open interproximal spaces, drilling a certain amount of sound tooth tissues, resulting in a less aggressive preparation step and maintaining all the peripheral enamel needed for carrying out adhesive cementation techniques [3,7,9,13,14].

Furthermore, a preoperative study of the case by means of a digital plan would allow to evaluate different insertion axes. Independently from the operative approach, digital tools like IOSs could be useful not only to check preparation thickness using superimposition applications but also to choose the most convenient insertion path; consequently, the prosthodontist can assess the presence of possible undercuts, whose removal would result in the sacrifice of a certain amount of tooth tissues, and choose the most conservative path
between axial and buccal, allowing just to round preparation edges and preserve sound enamel [3,7,14,25].

Intra-oral scans permit to evaluate both the occlusal clearance and the presence of unfavorable undercuts in real time during tooth preparation, enabling the clinician to immediately modify these areas; this specific software suite is particularly useful for unskilled operators that can take advantage of this function as a training tool and significantly improve patients’ comfort, since no correction appointments are needed to adjust tooth preparations [7,10,12,22].

Preoperative digital planning is crucial if the placement of implants is also required. The desired implant position can be previsualized in the clin-check, with the aligners being fabricated to keep the room necessary to place the fixture; moreover, the 3D shape of the final aligner can be easily transformed into a surgical template for computer-guided implant surgery in order to place the fixture with a flapless approach in the exact position previsualized in the digital plan [21,22].

Regarding patients’ discomfort and pain, computer-guided implant surgery has been proven to be beneficial in comparison with conventional implant surgery, achieving a satisfactory level of accuracy; in particular, the margin of error between virtual planning and post-operative radiographs was reported to be about 0.2 mm. Clinical complications with computer-guided implant surgery were described as negligible and comparable to those evidenced with conventional implant surgery. Moreover, in single-tooth edentulous spaces (particularly common after the orthodontic opening of the space in case of tooth agenesis), immediate loading subsequent to computer-guided implant placement is considered a well-accepted option to reduce treatment time [21,22].

5. Digital Impression

Optical impressions and IOS systems represent one of the most impressive innovations in the field of digital dentistry. After a correct training curve, such devices allow clinicians to significantly reduce the time required for making impressions, with the accuracy and marginal fit of optical impression systems being considerably improved in the recent decade [7,10,12,22]. Restorations produced with currently available digital IOS systems show clinically acceptable ranges of marginal gaps in both direct and indirect procedures [17–19].

Although scanning strategies could affect the precision of scans, the accuracy of IOSs was reported to be significantly more related to data acquisition technology (i.e., triangulation or stripe light projection, confocal laser microscopy, active wavefront sampling) than scanning protocols [26].

IOS systems are characterized by variable levels of overall accuracy in digital datasets. To date, there is no consensus regarding their accuracy in comparison with conventional elastomeric impression materials; some studies pointed out that IOSs provide similar or even better accuracy, whilst other investigations showed that they are less accurate than polyvinylsiloxane and polyether impression materials. Such controversial results might arise from several confounders, like the scanner tested, data acquisition technologies, light sources, imaging types and the necessity of coating and powdering [27].

The accuracy of optical impressions was reported to be clinically satisfactory and similar to that of conventional analog impressions both in single restorations (i.e., crowns, veneers, inlays, onlays, overlays, table-tops) and fixed dental prostheses up to five units. Conversely, controversial results were pointed out regarding the trueness and precision of IOS systems in full-arch scans and in edentulous arches [22,27].

Correct orthodontic preparation and positioning of teeth by means of aligners can significantly improve the quality of digital impressions, as preparation margins should ideally be placed supra- or juxta-gingivally with a minimum of 1 mm spacing between adjacent tooth surfaces being able to guarantee optional digital impression making. This is because the curvature of the margins recorded with commercial IOSs is significantly affected by clinical factors obscuring visibility, like tooth proximity and soft tissue overlapping [14,22].
The same considerations should be considered in interdisciplinary cases where an orthodontic space opening is necessary to position implant fixtures. Digital information relevant for prosthesis manufacturing is stored on the implant scan body in a specific format; information is kept in the coronal third of the scan body, and relative calculations are encoded by the scanning software. In contrast to the past, currently available scan bodies are characterized by simplified geometries, reducing scanning overamplification [14,22].

Implant angulation seems not to decrease the accuracy of optical impressions, while the error generated by scanning software is dependent on the operator’s experience, the distance between fixtures and reference points (i.e., teeth, other implants, soft tissues), and the depth of transmucosal paths [15,22].

The scientific evidence collected so far on IOS systems is neither exhaustive nor up-to-date; concerning conventional impressions, clinicians have to evaluate critically optical impressions, being aware of system-specific variations and technical limitations among IOSs. Orthodontic preparations by means of aligners could be useful to reduce operative drawbacks and to precisely make a digital plan, carefully evaluating the clin-check and properly positioning teeth in order to optimize the clinical features necessary to improve the accuracy of digital impression making [13,14,26].

6. Digital Designing

CAD software is in progressive development and allows to modify every single step of restoration designs; obviously, proper learning curves are necessary to correctly manage these types of software [18,19,25].

As the time reduction patterns for iterative learning are different according to the type of CAD system, such learning curves may differ depending on the systems themselves. As the operator’s expertise increases by means of iterative learning, the differences in learning times between the digital design programs have been reported to gradually disappear. Human factors and restorative skills play a pivotal role in a process inclined towards standardization; however, this, at the same time, simplifies results only if managed correctly [18,19,25].

The analysis and check-up steps described for treatment planning and digital previsualizations continue during the design and customization of prostheses, thanks to specific CAD check-up tools dedicated to the careful analysis of restoration thickness, occlusal contacts and potential esthetic outcomes [18,19,25].

7. Digital Manufacturing

To date, the types of CAD-CAM-machinable restorative materials range from waxes to resins, from all-ceramic materials to metal alloys, covering all clinical indications of digital prosthodontics and restorative dentistry. It is possible to already project and simulate the shape and volume of final restorations during the previsualization and clin-check steps, allowing to optimize the use of orthodontic aligners and achieve the proper placement of teeth for ideal function, biomechanics and esthetics [18,19].

Additionally, in the recent decade, manufacturing technologies were significantly implemented in the digital workflow. Side by side with conventional CAD-CAM subtractive fabrication processes (like milling, electric discharge machining, spark erosion)—clinically acceptable and widely validated but strictly subjected regarding working tips’ precision and dimensional fit—several additive manufacturing techniques were developed (such as selective laser sintering/melting, 3D printing, stereolithography, digital light processing, direct deposition printing, jetting) to overcome the limits due to undercuts and allowing to fabricate restorations regardless of their geometrical complexity. These techniques have been widely improved and integrated into the restorative digital workflow [18,19].

The development of a digital workflow has resulted in a time reduction concerning impression making and operative time; indeed, a full-digital approach may shorten the production time by 33%, with 100% of patients declaring that they prefer it in comparison to a conventional workflow. The advantages of digital workflows are as follows: shorter
clinical treatment time, simplified technical production due to minimal human intervention, high quality and precision of restorations, shortened treatment sequences and reduced number of appointments [7,23,28].


The progressive development and improvement of additive fabrication techniques are unstoppable, as is the variety of restorative materials that can be used in digital workflows. Nonetheless, the integration of protocols for complete full-digital protocols still needs to be completely standardized and validated [8,28].

The main challenge regarding this topic are represented by the rapid obsolescence of continuously developing novel technologies that require significant economic investments for both clinicians and dental technicians, the complete digital integration that needs different methodologies because of the various tools and manufacturing processes used, the shortening of expected learning curves and the resistance to change when implementing innovative protocols because of the popular use of conventional ones [7].

Dental digital tools are vastly available and currently offer a similar accuracy to conventional approaches; however, the more advanced a digital device, the longer the expected learning curve(s) [7].

The communication between interdisciplinary clinicians, dental technicians and patients can be efficiently managed with digital tools; particularly, virtual smile design systems, digital mock-up techniques and CBCT data can be easily and efficiently integrated, creating new possibilities and opportunities for full-digital patients [5,7,13,21,23].

Digital dental technologies are a very dynamic area and require frequent updates and upgrades since they could be easily surpassed by even more innovative systems.

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References

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