CLINICAL PROTOCOL WITH DIGITAL CAD/CAM CHAIRSIDE WORKFLOW FOR THE REHABILITATION OF SEVERELY WORN DENTITION PATIENTS

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SUMMARY

Objectives. The purpose of this paper is to investigate the effectiveness and to describe a clinical protocol with digital CAD CAM chairside workflow for the rehabilitation of severely compromised and worn dentitions.

Methods. This article reports 4 consecutive cases, where a clinical digital chairside workflow is used for the rehabilitation of severely compromised and worn dentitions. Advantages and limitations of this method compared with the traditional prosthetic protocol are also described and discussed.

Results. With all four patients treated with this protocol, we obtained a good aesthetic and functional result, improvement in chewing function, loss of cold sensitivity, better preservation of most of the left hard tissue and a good level of satisfaction.

In a two-year follow-up, all patients also maintained the condition obtained with prosthetic chairside rehabilitation, resulting in almost 100% cumulative survival rate.

Conclusion. Within the limitations of this study, we can assert that the aforementioned restorative treatment with digital CAD/CAM chairside workflow represents a valid alternative to rehabilitate this kind of patients, because it is a safe, predictable and personalized procedure but also it seems easier, faster and cheaper than traditional protocols.

Key words: chairside, CAD/CAM, Cerec, worn dentition, full-mouth rehabilitation.

Introduction

Worn dentition is a normal physiological phenomenon that is considered pathologic only if pulpal exposure or tooth loss occurred (1). It represents the dentist's challenge of the last millennium, because more and more patients suffer from this pathology and because the treatment plan is always very delicate (2).

From an epidemiological point of view, Van't Spiiker et al. study reported old people and males having more wear than females. It was found that:

- AT AGE 20: 1 in 33 patients (3%) has severe tooth wear
- AT AGE 70: 1 in 6 patients (17%) has severe tooth wear (3).

However, El Aidi et al. study has found that the prevalence of dental erosion is higher in the young population (children and adolescents) (4). It's also, nowadays, a very important challenge for oral health care (5).

According to European literature, erosion is much more important than friction as an etiological factor for worn dentition (6).

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From an etiological point of view, the loss of dental tissue can be the result of two kinds of causes:
- mechanical causes: friction and abrasion (7);
- chemical causes: erosion (6).

Combination of these causes: in patients with erosion, there is often dental friction, especially in those ones with a combination of dentinal exposure and vertical anterior overlap, as a result of a greater occlusal force of strong horizontal loads on exposed dentine (8, 9).

Attrition

It is the tooth loss structure through tooth-to-tooth contact. From a clinical point of view, it is different from erosion because areas of attrition show flat, shiny facets with sharp edges (7).
There are two kinds of attrition: physiological or pathological.
The physiological attrition is due to normal functions such as chewing and biting.
The pathologic attrition, otherwise, it may be due to four causes:
- functional mandibular movements: restricted envelope of function (10);
- interferences in the occlusion: parafunction (11);
- neurological stimulus (night bruxism) (12);
- dental structure anomalies, such as imperfect amelogenesis, imperfect dentinogenesis (2).

Abrasion

It is wear caused by friction between the tooth and an exogenous agent (2).
According to the exogenous agent type, there are four types of abrasion:
- brushing abrasion
- abrasion due to smoking pipe
- abrasion due to stressing habits
- abrasion due to human rites (7).

Erosion

It is the progressive and irreversible wear from corrosion (exposure of the tooth to an exogenous or endogenous acid), then it is due a chemical process that does not involve bacteria (13). From a clinical point of view, it is different from attrition because areas of erosion show cupped, satin finished facets with rounded edges (7).
It may be due to three etiological factors:
- extrinsic factors such as high consumption of swee/soft drinks, fruit juices and sugar in the diet;
- intrinsic factors such as bulimia nervosa, hysterectomy, gastro-esophageal reflux (GERD);
- idiopathic factors.

Regarding the worn dentition treatment, it is very difficult to set up because, usually, worn teeth are in a wrong place (they are overerupted). Less frequently, vertical dimension has been lost. As a matter of facts, the elements that make hard the treatment planning patients with worn teeth are:
- number of teeth needing treatment
- inadequate tooth structure to restore
- no space for the restoration
- need to alter the vertical dimension.

Moreover, patients at greatest risk of failure are those ones whose tooth wear is due to attrition (the teeth rubbing against each other); instead, if there is tooth wear but no evidence of attrition, the risk of failure is the same as any other patient (2).
Because of all these reasons, the determination of etiology, diagnosis and treatment plan is essential for the success of the restoration (14).
In other words, the treatment of the worn dentition can be divided into 3 phases:
1) accurate etiological, clinical, functional and aesthetic evaluation (accurate evaluation of the chewing condition) to find out all the causes of dental loss;
2) preventive and restorative phase;
3) maintenance program.

During the preventive and restorative phase first it is needed to try to reduce the effect of noxa. For example, for patients with parafunctions, a

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tooth guard (byte) is used; for incorrect feeding the diet is corrected; for excessive and incorrect brushing the oral home hygiene technique must be improved. Then it's possible to restore the worn dentition (15).
The approach of the restorative treatment is different according to the wear pattern:

- Patients with an anterior wear pattern: it is important to understand the need of a vertical dimension increase because, in most cases, a secondary eruption of the anterior teeth occurs, not followed by a vertical dimension loss. In these cases, methods such as selective orthodontic intrusion (to put the teeth back in the correct position) or elongation of the clinical crowns can be used.
- Patients with a posterior worn pattern: a common mistake in the treatment planning is to believe that the patient needs, as already mentioned before, to increase the vertical dimension (VDO). Usually, a secondary eruption of the diatoric elements occurs and the VDO is maintained. Then, as the precedent kind of patients, the treatment should include orthodontic techniques like intrusion or surgical techniques like crown elongation.
- In patients with an asymmetric wear pattern (with predominantly or exclusively localized worn areas on one side): depending on the etiology and the amount of secondary eruption of the worn teeth, the treatment planning should include orthodontic intrusion or surgical crowns elongation of the worn elements.
- In patients with a symmetrical wear pattern: the vertical dimension increase is really required (2).

We must say that the clinical challenge of severely compromised and worn dentitions is to preserve the already worn dental structure as much as possible, to achieve greater resistance and retention, but also to satisfy the increasing demands of patients for fast, personalized and highly aesthetic treatments (16).
As a matter of facts, it is better to perform a restorative adhesive-type treatment and make these restorations through a CAD/CAM digital workflow.
According to Magne et al., in fact, a restorative adhesive-type treatment is better because adhesive dentistry has demonstrated its effectiveness to restore the dental crown, allowing at the same time, the best preservation of remaining dental structures for both anterior and posterior teeth (17).
Magne et al. have demonstrated sufficient crown stiffness after ceramic veneer restoration on anterior teeth and the effectiveness of the immediate dentinal seal (SDI) with sufficient adhesive strength to the surface of the exposed dentine (18, 19).
In the past, according to traditional prosthetic techniques, preventive endodontic treatments and metal ceramic crowns (PFM) on one or both arches were required, resulting in a higher tooth loss and higher costs for the patient.
CAD/CAM technology compared to traditional methods seems to be faster, more accurate and predictable (20-22).
The milling of dental restorations resulting from a digital impression system offers to the patient the advantage of one single session, avoiding the complications associated with a temporary restoration (sensitivity, less aesthetics, pulpal damage, loss of retention, poor interproximal and occlusal contacts and outline) (23).
The purpose of this article is to describe a clinical protocol with digital chairside workflow for a full-mouth rehabilitation of severely compromised and worn dentitions, and to demonstrate its effectiveness.

Materials and methods

In this study, 4 patients (2 males, 2 females) aged between 45 and 74, healthy, non-smokers and with severely worn teeth due to chemical erosion and/or friction were recruited. On the basis of etiological factors, these patients have been divided into two groups:

- patients with chemical erosion wear
- patients with erosion/friction wear.

The following clinical protocol has been performed:

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1) Diagnosis:
   a) general and dental anamnesis
   b) clinical examination
   c) instrumental exams, such as: radiographic examination and photographic examination, with a Canon Eos 7D camera.
   d) evaluation of the possible state of contraction of the jaw and neck muscle. In case of positivity of a contraction state, we used a Lucia Jig and/or an anterior byte appliance to exclude intra capsular pathologies of TMJ, because the use of these devices can reveal a hidden pathology.
2) Alginate impression of both dental arches.
3) Determination of centric relation (CR) position and mounting the casts on an articulator, with the help of a facial arch (SAM 3).
4) Aesthetic Evaluation: on mounted models, we performed a diagnostic wax up. Then, we made an intraoral mockup that gave, both us and the patient, an indication of the new spatial position and the new shapes of the restored elements.
5) CAD/CAM chairside restorations.

Case reports

Case report 1

A 67-year-old male patient, D.F., globally healthy and non-smoker, came to our observation complaining about an aesthetic problem: "I'm worried because my anterior teeth are gradually shrinking and I'm afraid soon they will break. Besides, I don't like my smile" (Figure 1 a-c).
According to the protocol, we filled the anamnestic form.
At the clinical examination, we found a localized wear on the anterior group caused by an association of erosion (due to GERD) and friction (due to over-palatal position of the upper incisors). According to the evaluation of the lips-tooth facial relationship it was found that the incisal group position has changed over time. As wear has progressed, a process of overeruption of upper and lower incisors and an alteration of gingival geometry occurred.
In the posterior areas however, there were not a significant wear and the maintenance of the vertical dimension (DVO).
To complete the diagnosis, according to the protocol, a panoramic X-ray was requested and the patient underwent a muscular and TMJ examination to exclude any pathology.
After the etiological, clinical, functional and aesthetic evaluation for a treatment plan based on etiology, a periodontal evaluation and a professional hygiene session were performed.
As described before, most restorative treatments for severe dental erosion cases require a DVO increase as many studies support its high predictability (24). In this case, tooth wear was limited only to the anterior area, so we didn't increase DVO. To correct the anterior gingival architecture, to create the space for the restorations and to avoid further useless loss of healthy dental tissue, we decided for a selective intrusion of the upper and lower anterior group with invisalign aligners, better accepted by adult patients.
At the end of the orthodontic phase, we gained a better position of the gingival parabolas of anterior teeth and we created the space required to insert the restorations without a useless sacrifice of healthy tissues in already worn dental elements (Figure 1 d-f).
According to the protocol, having to restore the whole occlusion of the patient, we took alginate impression of upper and lower arches, we managed to get the patient in centric relation (CR) and we mounted the casts on articulator with the help of a facial arch. A diagnostic wax-up of both arches was then performed (Figure 2 a). To ensure that the forms of diagnostic wax-up were pleasing to the patient, an intraoral mock-up was tried. Subsequently we duplicated the gypsum diagnostic wax-up, we made dental preparations on the duplicate plaster and the software allowed us to over impose the scanning of the wax-up to that of the plaster preparations. In this way, we could obtain 28 provisional shells, joined in

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Figure 1
a-c) Pre-operatory condition. d-f) Post-orthodontic condition.

groups of three elements, which faithfully reflected the forms of diagnostic wax-up (Figures 2 b, c; 3 a, b).
In two close sessions, the 28 provisional elements were inserted, relined, articulated and cemented.
The resin provisional (VITA CAD/TEMP) was made with CAD/CAM CEREC system, DentsplySirona (Figure 3 c).
The patient wore the relined and articulated provisional prosthesis four months to check the adaptation of the gingival tissues and the neuromuscular system.
At the end of this phase, we scanned the functionalized temporary restoration, we scanned the final teeth preparations and thanks to the CEREC software, in four close sessions, we produced and applied the definitive prostheses.
In the first two sessions, we produced and delivered the posteriors areas crowns and bridges.
In the next two sessions, we produced and delivered the upper and lower anterior group.
The material chosen for the definitive prostheses is IVOCLAR EMAX CAD, a glass ceramic based on lithium disilicate (Figures 4 a-f; 5 a-f).
The completed case, and the result compared to the pre-operatory condition are shown in Figures 6 a-d; 7 a, b.

Case report 2

A 74-year-old female patient M.J, healthy and non-smoker came to our observation referring to be unhappy with her smile, feeling that her teeth were getting thinner and thinner and complaining sensitivity to cold (Figure 8 a-f).
According to the protocol, we filled the anamnestic form.
At the clinical examination, the patient showed a symmetric wear of her natural teeth due to gastroesophageal reflux erosion (GERD). In this case, again, GERD erosion caused in the anterior area an overeruption of teeth, an alteration in gingival geometry and a Spee curve alteration, worsening her deep bite.
Again, in the posterior areas, because of the presence of elements restored with fixed metal-ceramic prostheses and provisional methacrylate elements, we found a substantial maintenance of DVO.
To complete the diagnosis, according to the protocol, a panoramic X-ray has been requested and the patient underwent a muscular and joint examination to exclude any TMJ pathology.
After the etiologic, clinical, functional and aesthetic evaluation to formulate an etiology-based

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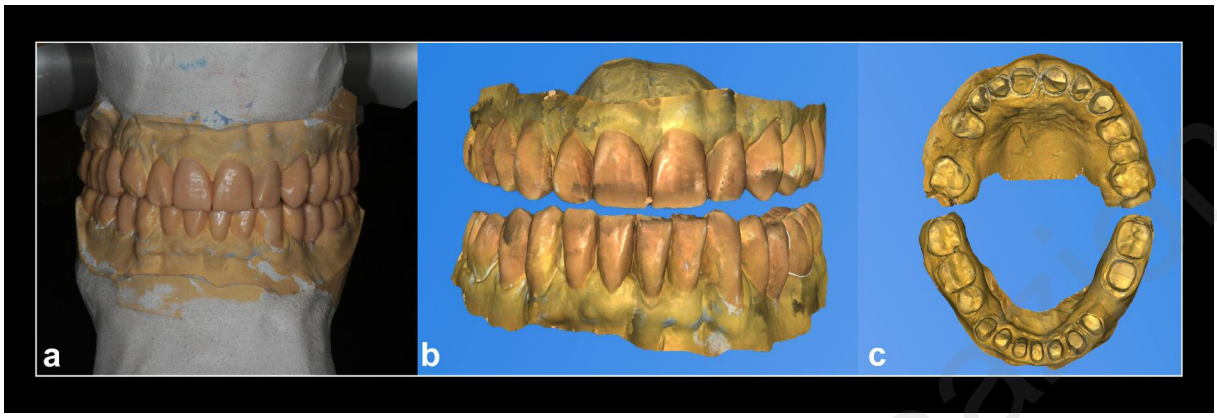

Figure 2
a) Diagnostic wax-up. b) Upper and lower arch wax-up scan. c) Upper and lower gypsum preparation scan.

Figure 3
a, b) Digital overimposing wax-up scan on prep scan. b) Upper and lower temporary restorations.

treatment plan, a periodontal evaluation and a professional hygiene session were performed.
At this point we started the restorations with the same phases of the precedent case, with the big difference that the patient categorically excluded orthodontic therapy and surgery.
To preserve the already worn tooth structures and to create the needed space for restorations, we increased the VDO.
According to the protocol, a diagnostic wax-up of both arches with increased DVO was performed (Figure 9 a).
To ensure that the shapes determined by the diagnostic wax-up were pleasing to the patient, a direct mock-up was performed (Figure 9 b, c).
The patient explicitly requested to avoid complete restorations (crowns) in the anterior area, preferring instead ceramic veneers, and asking to treat the anterior area first.
To satisfy the patient request, we proceeded this way:

- We scanned the diagnostic wax-up (Figure 9 d).
- Then, according to the scan, we designed occlusal upsets, which were milled in methacrylate and glued with an adhesive system to her natural elements or ceramic metal elements (Figure 10 a-f).
- At the end of this first phase, we obviously found an anterior open-bite (Figure 10 b), which allowed us to restore the palatal surfaces of the upper anterior eroded by acid re-

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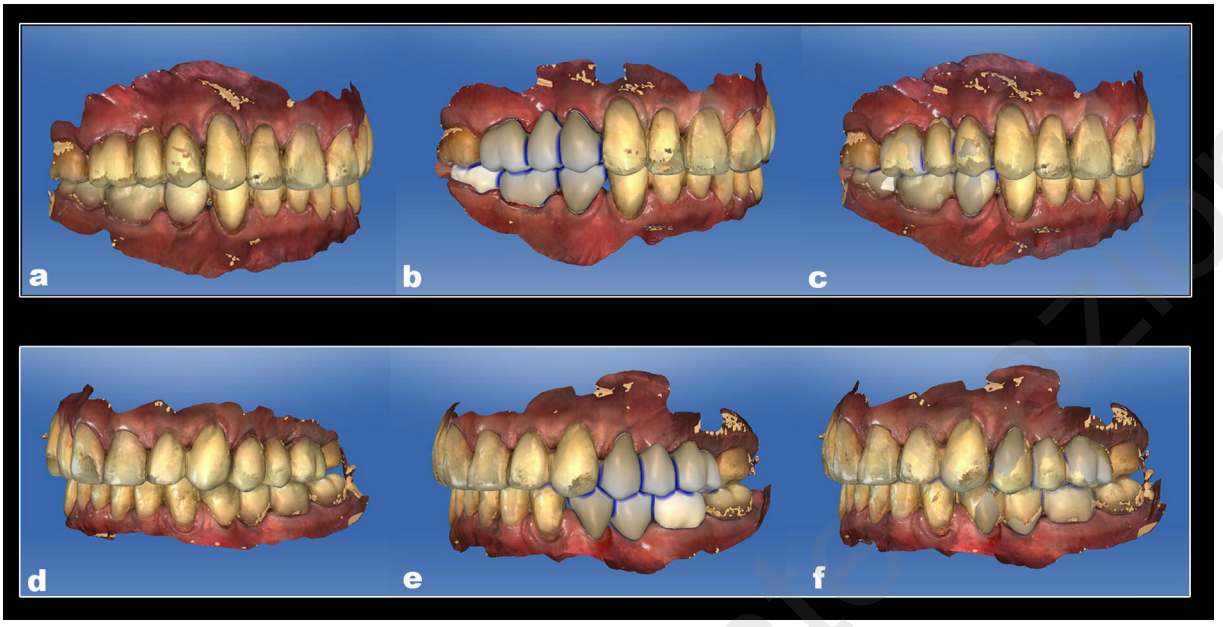

Figure 4
a-f) Temporary biocopy. Final restaurations projects-posterior.

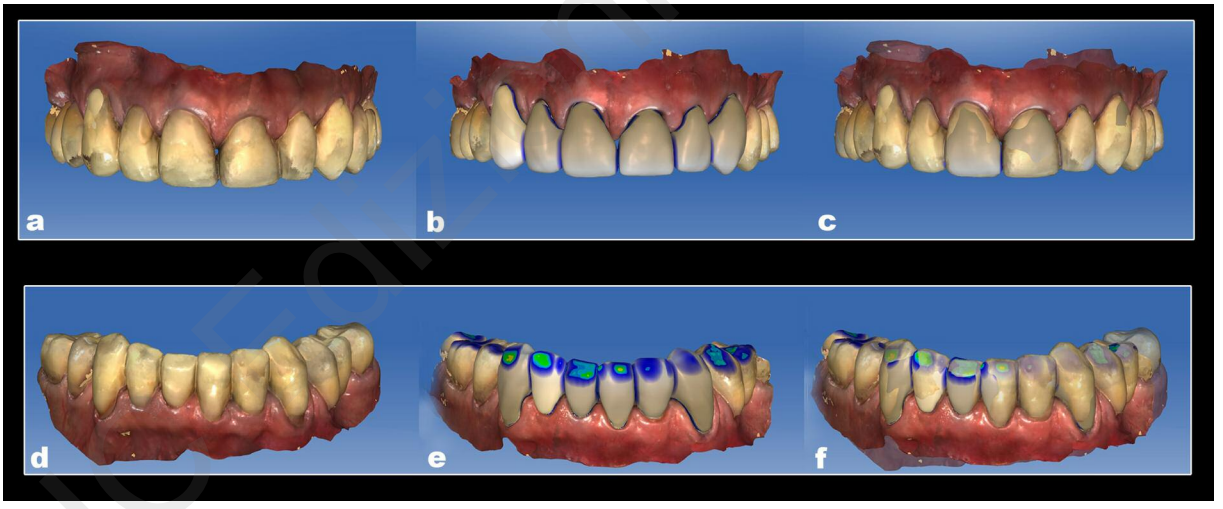

Figure 5
a-f) Temporary biocopy. Final restaurations projects anterior.

flux and the incisal margins of the lower anterior groups, with direct composite (Figure 11 a-c).

- Like the previous patient, in four close sessions, five upper veneers, six lower veneers, a three-elements implant-supported bridge and ten single crowns were designed in biocopy.

Vita Mark II feldspar ceramic was used for anterior veneers because of its excellent aesthetic characteristics; for the posterior area, we used a IVOCLAR Emax CAD lithium disilicate based

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Figure 6
a-c) Final restaurations (intraoral view). d-e) Final restaurations (extraoral view).

Figure 7
a) Pre-operatory condition. b) Post-operatory condition.

ceramic for its mechanical characteristics (Figure 11 d-f).
The result is shown in Figure 12 a-f.

Case report 3

A 70-year-old female patient, M.B., healthy and non-smoker, came to our office telling us for having an unpleasant smile.
According to protocol, we filled the anamnestic form.
At the clinical examination, we found a lightly worn dentition, with a problem of dental crowding (Figure 13 a-d).
To complete the diagnosis, according to the protocol, a panoramic X-ray was requested and the patient underwent a muscular and joint examina-

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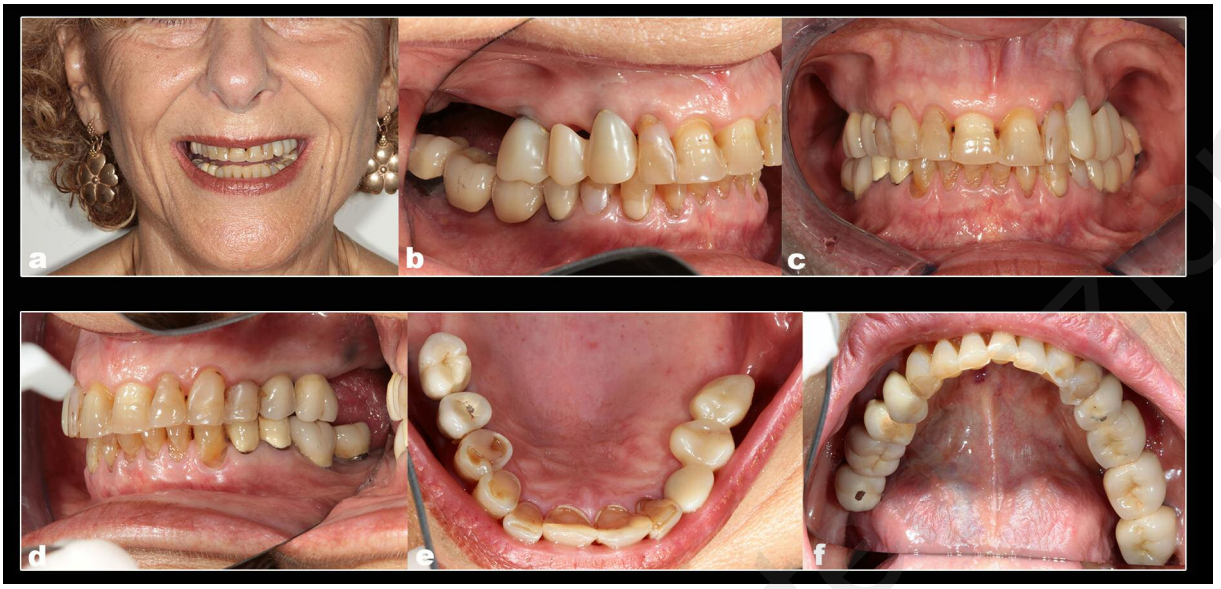

Figure 8
a-f) Pre-operatory condition.

Figure 9
a) Diagnostic wax-up. b, c) Mock-up. d) Wax-up scan.

tion to exclude any TMJ pathology.
The main patient request was to improve her smile without any useless sacrifice of dental tissue.

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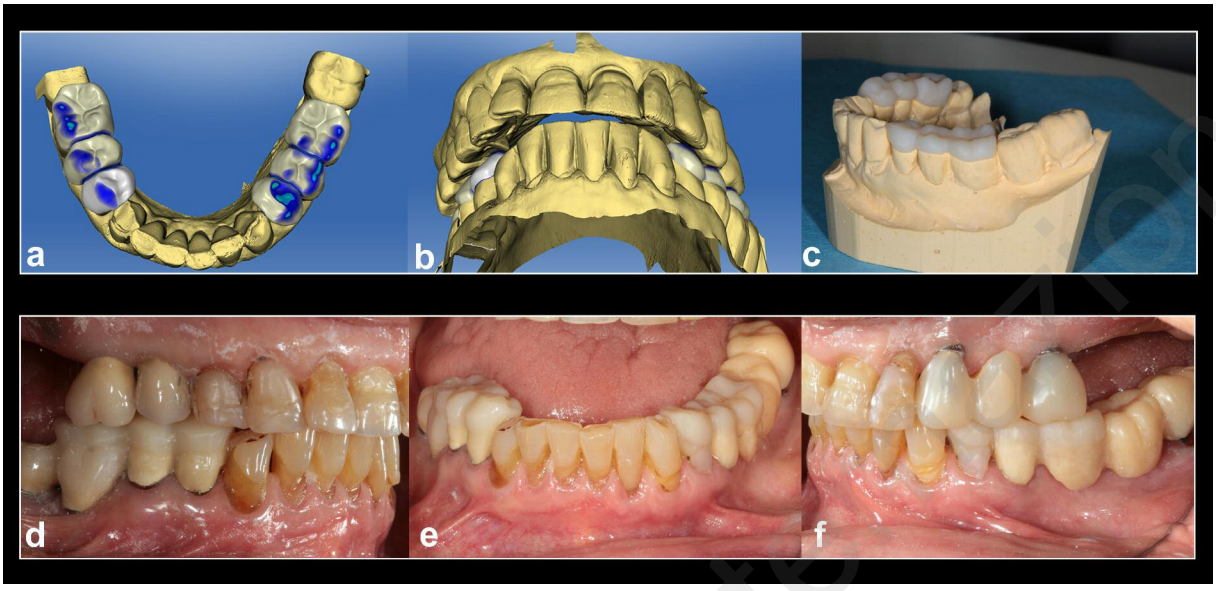

Figure 10
a-c) Occlusal offsets peoject. d-f) Occlusal offsets in situ.

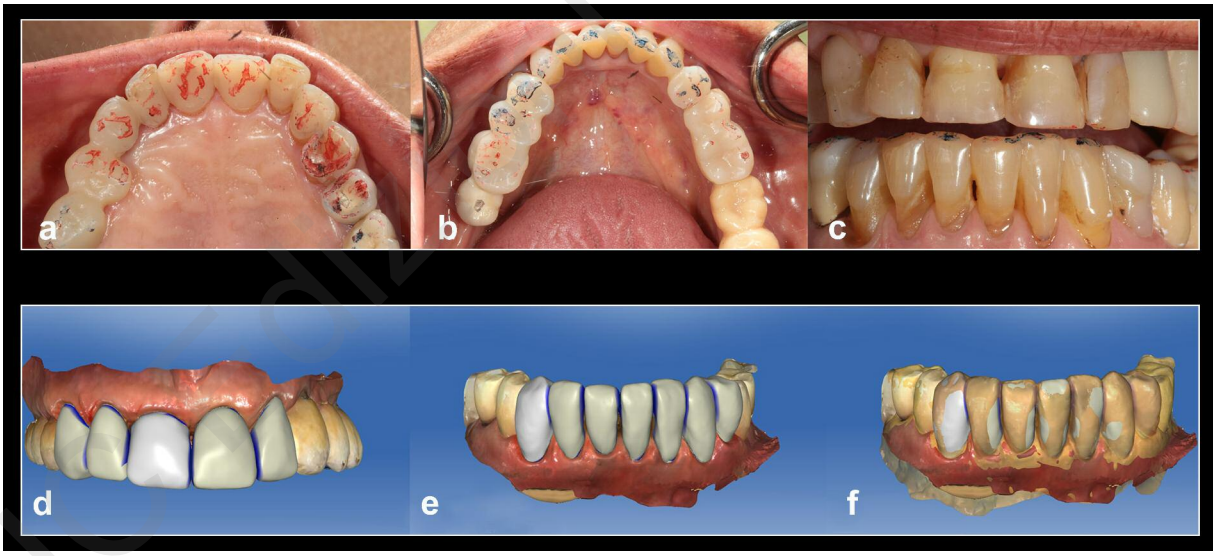

Figure 11
a-c) Anterior guide. d-f) Wax-up biocopy-posterior area project.

To fulfill her desire, our first goal was to correct the position of her natural teeth to minimize the amount of teeth preparations. We agreed to have an orthodontic therapy with invisalign aligners to correct the misalignment of her teeth.

At the end of orthodontic therapy, as requested by the protocol, we had a wax up of the upper arch, scanned it, mocked up it, prepared the

Figure 12
a-f) Post-operatory condition.

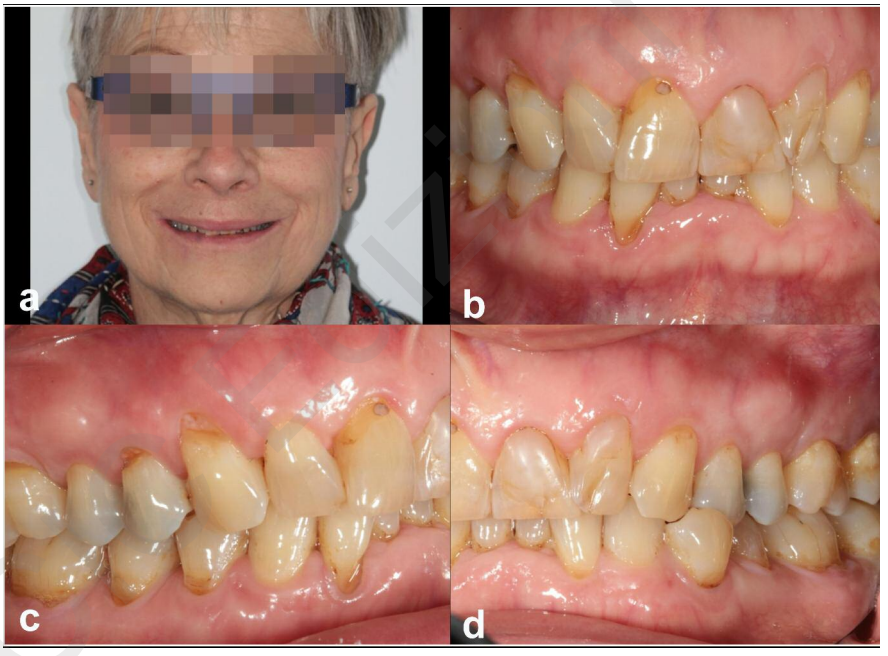

Figure 13
a-d) Pre-operatory condition.

eight anterior teeth, bio-copied the wax-up with the CEREC software, over imposed the wax up bio-copy on the teeth preparations and, in a single visit, we milled, finalized and delivered the eight lithium disilicate veneers (Figure 14 a-f).

Case report 4

A 45-year-old male patient, B.F., healthy and non-smoker, came to our observation, asking us to improve his smile (Figure 15 a-d).

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Figure 14
a) Post-orthodontic condition. b) Wax-up biocopy, anterior try out. c-f) Final restaurations.

Figure 15
a-d) Pre-operatory condition.

According to protocol, we filled the anamnestic form.
At the clinical examination, we found missing teeth n. 2.3, 2.4, 1.3, 1.5, 3.6 which have been replaced by implants.

To complete the diagnosis, according to the protocol, a panoramic X-ray was requested and the patient underwent a muscular and joint examination to exclude any TMJ pathology.
At this point we started the restorations. Accord-

ing to the protocol, a diagnostic wax-up of the upper arch has been performed and duplicated. Moreover, the gypsum model was prepared, scanned and over imposed on the wax up scan, and 10 provisional have been milled from an acrylic block.
We prepared the teeth. We also relined, articulated and cemented the temporary restorations. After four months, in a single visit, we scanned the functionalized provisional restorations, scanned the teeth preparations and the Cerec software allowed us to copy the provisional to produce the definitive restorations.
In this case, we used CELTRA DUO a Dentsply glass ceramic, which is a lithium disilicate reinforced with 10% of zirconia.
The result is shown in Figure 16 a-c.

Results

With all four patients treated with this protocol, we obtained a good aesthetic and functional result, improvement in chewing function, loss of cold sensitivity, better preservation of most of the left hard tissue and a good level of satisfaction. In a two years follow-up, all patients also maintained the conditions obtained with the prosthetic chairside rehabilitation resulting in almost 100% cumulative survival rate. No complications in fact have been recorded (no occlusal problem, no bridge fractures, no debonding of the veneers, no pulp-type issues); the only negative event was the chipping of the veneer of element 4.3 in the patient M.J.

Discussion

The clinical challenge with restoring severely compromised and worn dentitions is to preserve as much as possible the already reduced tooth structure as possible, to satisfy the increasing patients demands for fast, personalized and highly aesthetic treatments.
With this paper, we wanted to emphasize the clinical performance of digital impression and chairside CAD/CAM technologies for the full-mouth rehabilitations.
Clinicians, with this protocol, can treat patients in a single visit, respecting muscle-skeletal relation, respecting occlusal pattern, choosing extension and pressure of the occlusal contacts as well as the proximal contacts areas with high accuracy, having in their hands a selection of dedicated materials at the same times (23).
This protocol allowed us to reduce the time spent on the chair for the patient and the time in the laboratory, minimizing the stress of the dental team and financial costs for both the dental team and the patient.
Moreover, at the end of therapy, all patients were satisfied with the aesthetics and function of their new teeth (better dental color and shape, significant improvements in masticatory function, lost cold sensitivity, improved resistance to acidic

Figure 16
a-c) Post-operatory condition.

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erosion). As clinicians, we were satisfied of the result because all the parameters of the initial design have been maintained during the treatment.

Thanks to the lack of metal core and the adhesive luting procedure, this protocol showed a reduced invasive nature with a better tooth structure preservation that, as Magne shows in his studies, improve strength and retention of the restorations. Indeed, the use of materials that can be adhesively bonded to the tooth could make the preparation easier and faster compared with the traditional one.

Other advantages of this protocol are the following:

- a better communication within dental team and patient;
- a better acceptance of the impression procedure by the patient, due to the more superficial positioning of finishing line and to the absence of the impression material, with a consequentially faster and easier procedure than the traditional technique.

However, this technique shows some limits:

- technology costs;
- limited number of dedicated materials (material selection is still related to type of restoration);
- longer time session for the patient than the traditional protocol;
- the optical scanner can detect only what is visible, while the traditional impression techniques exploit the impression material viscosity to further displace gingival tissues and read slightly covered surfaces (25);
- it needs an adequate learning curve to use this software to avoid unwanted complications. An error during the virtual planning phase would be integrated into the definitive prosthetic work, resulting in patient's complications such as articular problems.

Conclusion

From the results of our study, we can assert that, nowadays, the aforesaid clinical restorative protocol treatment with digital CAD/CAM chairside workflow represents a valid alternative to rehabilitate this kind of patients, because it is a safe, predictable and personalized procedure but also it seems easier, faster and cheaper than traditional protocols.

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