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CAD/CAM technology aid in orthodontics and orthognathic surgery

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Abstract

The medicine has become a discipline deeply characterized from the technology both in diagnosis and in therapy.
Despite the planning and the realization of orthodontic devices is today still based on an approach typeÂ handicraftÂ they are more and more taking hold the digital technologies that are changing the dentistry.
The digital work flow of the CAD/CAM system foresees 3 steps :1) scanner acquistion in order to obtain 3D digital models 2) Planning via CAD software (computer aided design) to manipulate and to plan parts and devices 3) Building through CAM (Computer Aided Manifacturing) that allows fastly to get products elaborated and studied in the CAD.
The 3D digital models use determines a qualitative jump of strategic importance in the dental field. Such models allow to virtually operate on the patient to perform diagnostic analysis. Such method allowed the observation of the model under any angle, to effect the relative rotation of the dental arches, to verify the mandibular kinematics and valuate, through visualizations in semi-transparency, the dental occlusion. It has been guaranteed the possibility to effect easily a dimensional verifications on the models without the problem to use traditional tools of measure.
The substitution of manual procedures with a virtual system reduces the systematic errors. The system, producing digital data, allows easily to create a database reducing necessary space for the models in chalk and the times of production. CAD/CAM system is used in restorative dentistry, in Prosthodontics , Maxillofacial Surgery and Orthodontics. Especially in Orthognatic surgery is useful for treatment plan preparation and surgical splints production. In orthodontics has generated a new method of preparing the trays for indirect bonding.
The purpose of this job is to highlight the technology CAD/CAM aid in the orthognathic surgery and in the orthodontic field making reference to the studies published in literature on Pubmed in the last years, showing plus and minus.

Introduction

In a total quality view, also in this sector, it is needed to use the fittest technologies to gain the customer satisfaction and to develop solutions that allow an optimal use of them.(1)

It is necessary the use of an aid system to the planning of orthodontic devices quick, easy to use, low cost and reliable in terms of final results.

Computer-based technologies play an important role in all aspects of our daily life as well as in dentistry. (2)

The evolution of dental materials and advances in computer science led to a rapid development in dental CAD/CAM technology. During the past couple of decades the CAD/CAM systems were introduced in many dental offices and laboratories. Computers are used to collect data, design and manufacture a wide range of products in CAD/CAM systems.

These systems have long been used in industries but they were not available for dental applications until the 1980s (3).

CAD is the abbreviation for computer-aided design and CAM stands for computer aided manufacturing.

The CAD/CAM systems consist of three components:

1- A scanner to transform the geometry of a real object into a digital data.

2- Software for data processing

3- A production technology able to realize the desired product. (4)

ADVANTAGES AND LIMITATIONS:

Advantages of CAD/CAM systems:

No need for traditional impressions when intra-oral scanners are used.

Fewer visits .

Needs less manual procedures in laboratory .

Limitations of CAD/CAM systems :

High cost.

Need to know the technology (4).

Depending on the location of the components of the CAD/CAM systems, in dentistry there are three different possibilities:

chairside production
laboratory production
centralised fabrication in a production centre.
(4)

In the first case all components of the CAD/CAM system are located in the dental office. An intra-oral camera replaces a conventional impression. This allows to save time and appointments for the patient and for the dentist.

In the second case the job sequence is similar to the traditional one so the dentist takes the impression and it sends it to the laboratory. Then the laboratory produces the master cast. Next steps are performed in the laboratory. From master cast are created some 3D data thanks to the help of an extra oral scanner. First the data are elaborated, then the devices are designed

with computer thanks to the software CAD.
After the CAD-process the information will be sent to a milling device to produce the desired object geometry in the dental laboratory (4).
In the case of centralized production, the first and second stage of production take place in the dental laboratory while the third stage is done in central production. Scanners are connected to the production center via Internet. This procedure entails greater independence. (4)

Discussion

CAD/CAM system is used in ristorative dentistry, in Prosthodontics , Maxillofacial Surgery and Orthodontics . (2)
It is used for designing and manufacturing removable partial denture, metal frameworks through 3D printing(5), also in the field of implantology, in the creation of abutments and diagnostic templates.(6).
This system is used in maxillofacial surgery too.
The production of surgical splints using CAD/CAM System and the possibility of treatment plan in orthodontic surgery from a computer system has been the subject of various studies. (11-12-13)
A study produced in Barcellona during 2011 regarding 16 patients had the goal to focus on the advantages of 3D planning in predicting postoperative results.
For each patient has been elaborated conventional preoperative treatment plan and has been built surgical splints, these ones were used as study controls.
The preoperative treatment plans are first elaborated then moved to a 3D-virtual environment on
a personal computer (PC) and the surgical splints manufactured using CAD/CAM technology. In the operating room, both types of surgical splints were compared. The maxillary osteotomy line was used as the point of reference. Three months after surgery a second set of 3D images were achieved and used to reach linear and angular measurements on screen. Using the Intraclass Correlation Coefficient these postoperative measurements were related with the measurements reached when predicting postoperative results. The results showed a high degree of correlation in 15 of the 16 cases. The study highlights this software program used is reliable for 3D planning and for manufacturing of surgical splints using CAD/CAM technology. Nevertheless, further improvements in the development of technologies for the acquisition of 3D images, new software programs version and further studies of objective data are needed to increase precision in computerised 3D planning. (7)
In the article 3D planning and use of Computer Aided Design/Computed Aided Manufacturing surgical splints in orthognathic surgery has been highlighted the critical point to produce surgical spints in orthognathic surgery with 3D planning and CAD/CAM system.(8)
In the 3D studio you have the full vision of a craniofacial anatomical structure to calculate the dimensions in the 3-floor space into a single image and fix the bone and dental structures taking into account the rest of the facial anatomy. The effects of proportionality and facial symmetry are more clearly seen in the 3D study, this leads to the conclusion that the position in the simulation of ostetomized structures is more accurate when the study is conducted in 3D (9) (10)
CAD/CAM surgical splints are built from computed tomography or cone beam computed tomography which leads to have more detailed points of references and a better valuation of the involved anatomic structures compare to the 2D images. Surgical splints comes from a computerized process that allows reproducibility and reduction of craft errors. (8)
About the orthodontics the CAD/CAM system has been used for the orthodontics appliances production too. (14)
CAD/CAM technology has been used as a new model for the indirect bonding that foresees the impression taking, a plaster model on which the brackets are positioned by fixing the positions through a tray. This one is then used to transfer the brackets to the patient (15).
The method for indirect bracket bonding is made of several steps. First the silicone impression taking is done, starting from this were produced the casts. The initial model of malocclusion were scanned by 3D scanner examining the model from various perspectives to create a complete 3D view,. The result is an area consisting of many thousands of minute triangles (standard triangulation language area that can be observed and processed on a computer with dedicated software). After using the dedicated software (CAD) the operator virtually positions the commercial bracket chosen (previously incorporated in the software database) onto each tooth at the height wanted. When brackets have been rightly positioned, the fabrication of the rapid prototyping trays (RPT) can start. A special command produces a cubic-like figure with the same maximal bracket dimensions. A positive of the RPT, where the real bracket will be placed, has been made. To create the negative of the site, the cubic figure is covered with a virtual acrylic-like material, to show the tray in a raw state. Trays with

adequate mesiodistal dimension are preferable because they prevent interproximal interferences. Further trays for each tooth could be reused in the next treatment phases where rebonding of some brackets is necessary. To avoid errors in positioning, the RPT should overlap the incisor or the cusp margins enough to give a point of reference for the vertical dimension. To reach an immediate mesiodistal reference point, the RPT should cover until to the interproximal space for the incisors and at least 1 mm laterally from the bracket site for the canines and the premolars. The gingival margin should be cut off from the definitive RPT. Using a high end quick (CAM system) prototyping machine the virtual trays can be converted into the final real product, made of a rigid-elastic plastic material. (16) Once the trays have been built and delivered, the bonding procedure can start. The buccal esame surfaces are cleansed and polished with pumice and rubber cups, washed with water and dried. A 37 percent phosphoric acid gel is used to acid-etch the teeth for 30 seconds. The teeth are rinsed again and dried, and the characteristic chalky white appearance must be present. The primer is applied to the etched surface in a thin film. An adequate quantity of adhesive paste is applied to the bracket bases and the brackets were entered into the RPT sites. Then the RPT can be positioned in the mouth and pressed onto the dental surfaces according to the anatomy of the teeth and the adhesive cured. When the tray is taken off, the bonded bracket remains on the tooth. This procedure must be repeated to bond the full arch. (16)

This procedure includes 2 issues: inaccurate bracket positioning and lengthy chair time.

Commercial brackets in the software database are positioned measuring the height, mesiodistal position and angulation. This allows the exact bracket placement and decreases the potential for error. However, thatâ€™s no a guarantee to reduce the mean bracket placement errors. The quality of the initial impression is really important and during the virtual bracket positioning, the user must avoid the contact with the dentition of the opposite arch; this could cause accidental debonding. Compared with the direct bonding, the indirect RPTs could help the clinician save time by reducing the time necessary to check the bracket position on each tooth. (16)

The purpose of a study conducted by Brown et all was to investigate the clinical effectiveness and efficiency of CAD/CAM orthodontic appliances compared with directly and indirectly bonded orthodontic brackets. This retrospective study included 3 treatment groups: group 1 patients were direct bonded with self-ligating appliances, group 2 patients were indirect bonded with self-ligating appliances and group 3 patients were indirect bonded with CAD/CAM self-ligating appliances. Complete pre-treatment and post-treatment records were obtained for all patients. The American Board of Orthodontics (ABO) Discrepancy Index was used to evaluate the pre-treatment records and the post-treatment outcomes were analyzed using the ABO Cast-Radiograph Evaluation. All data collection and analysis were finalized by an evaluator. Following the achieved results there were no statistically important differences in the ABO Discrepancy Index or the ABO Cast-Radiograph Evaluation among the groups. Treatment timing for the 3 groups were deeply different; the CAD/CAM group was the shortest compared to the direct bonded and indirect bonded groups. The number of treatment appointments for the CAD/CAM group was really lower than the direct bonded group.

The CAD/CAM appliance was more efficient regarding the treatment duration, nevertheless the reduction in the number of appointments was minimal. Further investigation is necessary to better quantify the clinical benefits of CAD/CAM orthodontic appliances.(17).

Conclusion(s)

Currently the digital technologies such as the CAD / CAM system are increasingly taking hold in the design and implementation of dental appliances, leading the dentistry to a new era. Thanks to theÂ simplification of the workflow, it has led to a reduction in working time. The decrease of craftsmanships replaced by the computer and the implementation of a precise and reproducible method has allowed a reduction of the errors by providing to the patient a better quality of treatment. The use of intraoral scanner allows the removal of plaster models, but its price is still high being a relatively new technology. The goal is to develop an aid system for designing orthodontic devices that is quick, easy to use, cost-effective and reliable in terms of final results. About the application of CAD / CAM technology in orthodontic field the real improvement has beenÂ a new method of preparing trays for indirect bonding.The main advantages of this new method, compared with traditional indirect bonding, are the decreasing of the manufacturing stages and the bracket positioning optimization offered by CAD/CAM tecnology. This leads the dentist to save time. A potential limit of the RPTs is the impossibility of correcting the bracket position due to the presence of the tray during the bonding procedure. A wrong bracket position on the 3D model can be discovered only after the tray removal. The presence of light-cured paste around the bracket can be showed only after the tray is removed. So we need to apply an adequate quantity of adhesive paste. About the disadvantages, we can declare that CAD / CAM technology foresees a high economical investment, therefore not accessible to all and the master of the technology.Randomized controlled trials are needed to compare the effectiveness of this technique with

traditional techniques.

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