Comparative evaluation, effectiveness and validity of 2 systems in the surgical planning of dentofacial deformities

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Abstract

Purpose

Over 70% of patients suffering from dentofacial deformity mention esthetics as the biggest issue pushing them to look for orthodontic and orthognathic treatment. At present, several software for computer-aided surgery have been released on the market, this surgical planning software allow surgeons to manipulate digital representations of hard and soft tissue profile tracings and subsequently morph the pretreatment image to produce a treatment simulation. The aims of this study was to investigate and find the difference between 2 of the most used digital software in the pre-surgical planning for patients affected by dentofacial deformities.

Methods

That was granted by using the following parameters: usability, validity, timing, accessibility, efficacy and predictability of the pre-surgical planning and the software costs. Ethical approval, to access and use the data, was obtained from the Federico II Research Ethic Committee (371/2019, approved in 21/02/2020).

Results

Analyzing the results obtained from our study, it is correct to define both software tools useful and valid in the digital surgical planning for treatment of patients with dentofacial deformities. Each software has negligible differences in performance that do not in any way affect the success of the surgical planning.

Conclusion

Despite a slight difference regarding the costs for the purchase of the license, which see the IPS software slightly more expensive than the Dolphin software, the IPS software represents not only a valid alternative to the most popular and tested Dolphin Imaging software, but it is even inclined to evaluate it better in terms of accuracy, effectiveness, and reliability.

Introduction

Over 70% of patients suffering from dentofacial deformity mention esthetics as the biggest issue pushing them to look for orthodontic and orthognathic treatment [1–5]. In the beginning of orthognathic surgery in 1970s, surgeons used patient photographs with profile tracings. In the 1980s, computer-generated line drawings of the profile based on hard tissue changes became possible and by the mid-1990s, treatment simulation software started to allow surgeons to virtually plan surgeries [6–9]. Technological evolution has led to the production of computers with increasingly greater computing capabilities. This factor has made it possible to develop the CAD CAM and virtual design technology upon virtual planning software are now based. At present, several software for computer-aided surgery are available on the market: Dentofacial Planner Plus (Dentofacial Software, Toronto, Ontario, Canada) (DFP), IPS (IPSCaseDesigner KLS Martin Group) Quick Ceph (Quick Ceph Systems, San Diego, Calif), and Dolphin Imaging (Dolphin Imaging Software, Canoga Park, Ca) (DI), among others [10–16].

The aim for each of these software is always to realize surgical split that can allow the surgeon to transfer the virtual planning on the operative field. Each software has different graphic interfaces and different levels of automation and customization.

This surgical planning software allow surgeons to manipulate digital representations of hard and soft tissue profile tracings and subsequently morph the pretreatment image to produce a treatment simulation. To our knowledge nowadays there are no studies that analytically evaluate the intuitiveness, profitability, and speed of digital workflows of the schedules among the various software available.

Therefore, the goal of this study is to investigate and find the difference in terms of usability between 2 of the most used digital software for virtual planning in patients affected by dentofacial deformities, the well-proven Dolphin Imaging and the emerging IPS Case Designer.

Material And Methods

A retrospective observational, no-profit study was set on sample of patients admitted in our Maxillofacial unit for dentofacial deformities. From 2019 to 2020. We have randomly enrolled 10 patients selected from our medical records. All clinical investigations and procedures were conducted according to the principles expressed in the Declaration of Helsinki. Ethical approval, to access and use the data, was obtained from the Federico II Research Ethic Committee (371/2019). The pre-operative (Cone Beam Computer Tomography-CBCT) (Planmeca ProMax® 3D s, PLANMECA OY, ASENTAJANKATU 6, FIN-00880 HELSINKI, FINLAND) scans as well as facial scans and dental cast 3D models (PLANMECA®, https://www.planmeca.com/it/informazioni-stampa/press-room/planmeca-emerald-s) (STLStandard Triangulation Language-format) were acquired within one month of surgery. In order to better standardize the comparison, all the CBCT scans were acquired by the same operator (E.C), and the patients have been scanned in the centric relation (the most retruded, unstrained position of the mandibular condyle within the temporomandibular joint (TMJ), that is, within the glenoid fossa) [17]. The

Facial scans were acquired by the same operator keeping the patient's head position in the NHP by using 3DMD system (3dMD Technologies Ltd, 3200 Cobb Galleria Parkway, #203, Atlanta, Georgia 30339 USA). The two medical Software used for comparison were: Dolphin Imaging (version 11.9, Dolphin Imaging Software, Canoga Park, California) and IPS (IPSCaseDesigner KLS Martin Group, version 2.0). To reduce the errors in the study, the data was processed by the same computer (Dell Precision Tower 5820, ©2021 Dell Inc.) and acquired by the same operator for both groups. We based our comparison on 7 different outcomes to better highlight the differences between the two software.

Time

We used time as a variable to underline the Software performances, measuring all the phases of acquisition of the 3D scans, facial scans, intraoral scans, the data loading (CBTC processing) and the time required for complete surgical planning. We have also calculated the "learning curve", calculating the time required for the complete surgical planning for all the 10 patients by an inexperienced operator, to visualize the lowering of the time required for the planning at the increasing levels of experience of the operator.

Fundamental investigations

Fundamental investigations refer to the specific elements (instrumental investigations) the software needs to upload in the system to complete a surgical planning.

Linearity of planning path

We used this tool to underline differences between the two software in terms of simplicity and intuitiveness of use of the software itself. To pursuit a standardized comparison, we selected as comparative item the number of "windows" opened to proceed in the planning path, without any form of interruption or trouble caused by the software.

Surgical transfer

Surgical transfer is meant to define which of the two software allows the surgeon to transfer more accurately what has been planned in the operating room by providing occlusal splints and planning reports. Surgical transference was evaluated through a numerical evaluation in tenths carried out by the operators (2 Surgeons and 4 residents) about the level of appreciation after facing with the effectiveness of the surgical planning and the accuracy of occlusal splints in the operating room. Participants evaluated the model using survey ratings based on a 5-point Likert scale.[18] (See Fig. 1)

Basal specifics and costs

We included in the comparison information about the costs and the basal specifics, such as minimal requirements.

Results

Sample Features

(7 males, 3 females aged from 18 to 35) with an age average (24±3,4) affected by dentofacial deformities (7 patients affected by class III malocclusion, 3 patients affected by class II malocclusion)

The results of the comparison are listed below

Time

The two software Dolphin Imaging and IPS have comparable complete **planning times**. Small differences see the IPS software being, with the same data of a single patient, slightly faster, with an average time saving of 18.4 (± 19.2) minutes.

The learning curves show a **slope**, albeit similar, higher in the points inherent to the first measurements with the Dolphin Imaging software, suggesting also in this case a greater difficulty (and therefore a longer planning time), for the first measurements of a novice operator.

CBCT acquisitions show a substantial difference between the 2 software of /2,06±0,52/ seconds in favor of *Dolphin Imaging*.

Analyzing the data acquisition time records of the **intraoral scans** of the two software it appears that Dolphin Imaging is faster than IPS in the 10 measurements by / 1.03 ± 0.24 / seconds.

The analysis of the results related to the acquisition of **3D facial scans** once again attests how the Dolphin Imaging software proves to be more performing, guaranteeing an average time saving of / 1.46 ± 0.46 / seconds. (Tab. 1)

Fundamental investigations

Both softwares require 3D facial scans, facial CBTC, and intraoral scans. Both software does not require the execution and download of radiographic data (Orthopantomographic X-ray and Tele-skull X-ray in the Antero-Posterior and Latero-Lateral projections) but, although capable of deriving them from CBTC data, only Dolphin Imaging uses these instrumental investigations in programming. (Tab.2)

Linearity of programming path

The number of windows needed by the operator to complete a plan with the Dolphin Imaging software is 17, three more units compared to the windows needed to complete a planwith the IPS software (14). Dolphin Imaging software uses the first 3 windows for loading the patient data sheet, unlike the IPS software (2). IPS software requires one less window to ensure the occlusion overview, integrated in the next window for the construction of the occlusion scan, a missing step in the programming of the Dolphin Imaging software (programming does not require this data).

Surgical transfer

The effectiveness of surgical planning appears to be comparable between the Dolphin Imaging and IPS software, with a slight preference for the latter software, with an average evaluation value of 7.4 against the average value of 7.3 at Dolphin Imaging software. A differential of 0.1 is on the other hand lower than the value of the SD (0.75) making the differential itself statistically irrelevant. The analysis of the results referred to the evaluation of occlusal splints in the operating room shows an absolute comparability, attesting to both software an average value of 7.25. (Figure 1)

Basal specific and costs

1. **Minimal Requirement** (directly taken from https://dolphinimaging.it/it/products/3d/dolphin-3d/; https://www.klsmartin.com/en/products/individual-patient-solutions/ips-casedesigner/?L=%2525252Fetc%2525252Fpasswd). (Tab.3)
2. **Costs**

Dolphin Imaging offers flexible plans to their customers, the basic cost of license starting from **$10,000** per license, in order to calculate the total cost of ownership (TCO) which includes: customization, data migration, training, hardware, maintenance, upgrades, and more;

IPS CaseDesigner is offering few plans to approach their customers, having then two different licenses. One is an Office License, at a price of **10.900 €**, only to be disposable for 2 users and typically used for medical offices. The latter (the one of most interest us) is the Hospital license, coming at a price of **14.900 €**, disposable for up to 6 users and typically used in hospital maxillofacial departments. The cost includes maintenance (comprehensive itself with free support and updates) only for the first year.

Statistical Analysis

Data management and analysis was performed using a T test (Microsoft Excel Statistics for Windows, Version 3.0. Armonk, New York: IBM Corp.). The level of significance was set at 0.05 ($P<0.05$). Data referring to planning measurements for the two software were judged significant with $p<0.01$. Statistical analysis of the acquisition of oral scans, facial scans and CBCT showed how the measurements are not statistically significant given the small sample size and the low variability of the data with $p> 0.5$.

Discussion

Every year thousands of patients elect to undergo combined surgical-orthodontic treatment to ease correction of severe jaw deformities [1–5]. Due to the complex nature of the dentofacial anatomy, orthognathic surgery often requires extensive presurgical planning [6–8]. In recent years, the rapid development of fast and affordable digital computer has revolutionized medical surgery [1]. This revolution has affected orthodontics in many ways and the best improvement was given using surgical planning tools. In the years, the advent of imaging software programs has proved to be useful for diagnosis, treatment planning, and outcome measurement. Therefore, over the years, the use of Virtual Surgery Planning software for education, pre-operative assessment, pre- surgical planning, and measurement have become very prevalent as, in recent days, market gives various options for the surgeon to choose, Dentofacial Planner Plus (Dentofacial Software, Toronto, Ontario, Canada) (DFP), IPS (IPSCaseDesigner KLS Martin Group) Quick Ceph (Quick Ceph Systems, San Diego, Calif), and Dolphin Imaging (Dolphin Imaging Software, Canoga Park, Ca) (DI), among others.

The aim of our study is to make a comparison between two surgical planning software on the market for the study and planning of orthognathic surgery: the well-known and proven Dolphin Imaging, and the emerging IPS. Willinger et al discussed a comparison on these two VPS based on accuracy of soft tissue prediction of 2 in patients undergoing an intraoral quadrangular Le Fort II osteotomy [19] and a comparison based on feasibility, time consumption, and costs in a standardized workflow for a modified intraoral quadrangular Le Fort II osteotomy (IQLFIIO) [20]. As we know, in the actual literature there is any work who compares the VPS Dolphing Imaging and IPS discussing items as Accuracy, Validity, Time and Usability in the surgical planning of Dentoskeletal Dismorfia.

Analysis of the results on the measurements of the acquisition times

Analyzing the measurements, the first difference in performance is evident regarding the acquisition times of the CBCT data, with an average difference in the acquisition to be in favor of the Dolphin software with more effective imaging in both single acquisition and long run. Moreover, it is interesting to note how data acquisitions of the 10 CBCTs are much more heterogeneous in the case of the IPS software, a sign of greater variability. Analyzing the data acquisition time records of the intraoral scans of both Dolphin Imaging and IPS software, the first result is the variation of the acquisition times that sees Dolphin Imaging software to be more performing, thereby faster than IPS in the ten measurements.

Both software have comparable data homogeneity, demonstrated both in the ten measurements of the two individual software and in the comparison between the two software acquisition times, specifying that this homogeneity can also be correlated to the relative " lightness" of the intraoral scan data. The analysis of the results related to the acquisition of 3D facial scans offers interesting insights, confirming once again how the Dolphin Imaging software proves to be more performing. The analysis of the acquisition times highlights a relative heterogeneity of the IPS software alone, both in the single ten measurements, and in the comparison with the recordings of the Dolphin Imaging software, which also in this case proves to be faster. It would therefore seem that Dolphin Imaging software is more powerful in managing a large amount of data.

Analysis of the results related to the study of the linearity of the programming path

The analysis of the results related to the number of open windows to determine the linearity of the planning path demonstrates similarity.

The number of windows required by the operator to complete a planning with the Dolphin Imaging software is 17 windows, greater than the 14 windows required to complete a planning with the IPS software. In addition to the number of windows, the intrinsic difference of the specific purposes was also evaluated: the Dolphin Imaging software uses the first 3 windows to load the patient data sheet, unlike the 2 used by the IPS software.

The IPS software requires one less window to ensure the occlusion overview, integrated in the next window to load the occlusion scan, a missing step in the planning of the Dolphin Imaging software. Bigger " saving" for the IPS software is given by the latter not needing to use the radiographic data (orthopantomography and telecranium).

The phases inherent to the actual planning can be absolutely overwritten for the two software.

Each software requires eight windows to plan the osteotomies and design the occlusal splints. The difference in the number of open windows in planning would suggest greater ease to use of the IPS software. Ultimately, the investigation into the linearity of the planning path does not see the predominance of one software over the other, bringing out overlapping results in terms of performance and usability.

Analysis of the results of the accuracy of the surgical transfer

The analysis of the results shows, according to the evaluations carried out by the operators, that the effectiveness of the surgical planning appears to be comparable between the two software Dolphin Imaging and IPS, with a slight preference towards the latter software, with an average evaluation value of 7.4 against the average value of 7.3 attested to the Dolphin Imaging software. A difference of 0.1 is less than the value of the SD (0.75), making the differential itself statistically irrelevant. The analysis of the results referred to the evaluation of occlusal splints in the operating room shows an absolute comparability, attesting to each software an average value of 7.25.

Analysis of the results regarding the fundamental investigations

Both software require 3D facial scans, CBTC and intraoral scans. The only difference comes from the occlusal scans as this tool is only required by the IPS. Both software do not require the execution and download of radiographic data, (Rx Orthopantomography and Rx Telecranium in the Antero-Posterior and Latero-Lateral projections) which for IPS are not necessary for planning, while for Dolphin Imaging they can be extrapolated directly from the CBTC data.

Analysis of the results regarding the specifications and basic costs

the two software have slightly different costs for the purchase of the license, with the Dolphin Imaging software proving being slightly cheaper. The basic specifications are comparable, with the only major difference being that the Dolphin Imaging software does not have a version available for the Mac OS operating system

Conclusion

Despite the large presence of software dedicated to three-dimensional virtual planning in the treatment of dentoskeletal deformities, we decided to rely specifically on the two most used software. IPS Case Designer and Dolphin Imaging, which stand out for their accuracy, reliability, and graphic rendering.

Analyzing the results obtained from our study, it is correct to define both software tools useful and valid in digital surgical planning for the treatment of patients with dentofacial deformities. Each software has negligible differences in performance that do not in any way affect the success of the surgical planning. Despite a slight difference regarding the costs for the purchase of the license, which see the IPS software slightly more expensive than the Dolphin software, and net of the basic specifications, the IPS software represents not only a valid alternative to the most popular and tested Dolphin Imaging software, but it is even inclined to evaluate it better in terms of accuracy, effectiveness, and reliability.

We can therefore conclude that the introduction of 3D virtual planning in orthognathic surgery has made it possible to significantly improve the phases preceding the surgery by offering the surgeon the possibility of obtaining an accurate plan and reliability superior to that extrapolated from the single articulator. However, it should be noted that all this cannot be separated from a careful clinical examination or from the preparation and experience of the surgeon.

Declarations

Acknowledgement

All authors have viewed and agreed to the submission

Data Availability Statement (DAS)

All data generated or analysed during this study are included in this published article (and its supplementary information files)

Financial and competing interest

The authors have no relevant financial or non-financial interests to disclose

Author Contribution

All authors contributed to the study conception and design. All authors read and approved the final manuscript.”

Ethic Committee: All clinical investigations and procedures were conducted according to the principles expressed in the Declaration of Helsinki. Ethical approval, to access and use the data, was obtained from the Federico II Research Ethic Committee, Advanced Biomedics Sciences Departement (371/2019).

Informed consent: Informed consent was obtained from all individual participants included in the study.

Consent to publish: The authors affirm that human research participants provided informed consent for use and publication data.

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Tables

Table 1
Software comparison data: planning time, acquisition time for CBCT, intraoral scan, facial scan.

	Time to complete planning			Acquisition time of CBCT			Acquisition time of oral scans			Acquisition time of facial scans		
Patients	**Dolphin Imaging**	**IPS**	**/Variation/**	**Dolphin Imaging**	**IPS**	**/Variation/**	**Dolphin Imaging**	**IPS**	**/Variation/**	**Dolphin Imaging**	**IPS**	**/Variation/**
Patient 1	231	164	/67/	12,77	14,21	/1,44/	4,20	5,41	/1,21/	5,56	7,02	/1,46/
Patient 2	116	95	/21/	12,67	15,01	/2,34/	4,10	5,20	/1,10/	5,47	6,49	/1,02/
Patient 3	97	66	/31/	12,98	14,69	/1,71/	4,23	4,96	/0,73/	5,21	6,78	/1,57/
Patient 4	55	52	/3/	12,15	14,10	/1,95/	4,57	5,17	/0,60/	5,67	7,59	/1,92/
Patient 5	58	49	/9/	12,49	14,43	/1,94/	4,13	5,19	/1,06/	5,51	7,14	/1,63/
Patient 6	50	46	/4/	12,53	14,73	/2,20/	3,87	4,87	/1,00/	5,13	6,86	/1,73/
Patient 7	57	50	/7/	11,90	15,08	/3,18/	4,27	5,27	/1,00/	5,41	7,17	/1,76/
Patient 8	49	41	/8/	12,70	14,20	/1,50/	3,97	4,99	/1.02/	5,87	6,93	/1,06/
Patient 9	52	33	/19/	12,79	14,63	/1,84/	4,21	5,71	/1,50/	5,76	6,74	/0,98/
Patient 10	44	29	/15/	12,69	15,19	/2,50/	4,25	5,35	/1,10/	5,49	7,18	/1,69/
Average time	80,9(± 57,7)	62,5(± 40,2)	/18,4(± 19,2)/	12,57 ± 0,32	14,63 ± 0,39	/2,06 ± 0,52/	4,18 ± 0,19	5,21 ± 0,26	/1,03 ± 0,24/	5,51 ± 0,23	6,99 ± 0,30	/1,46 ± 0,46/

Table 2
Fundamental investigation required for a complete surgical planning

Dolphin Imaging	***IPS***
Cone Beam Tc	Cone Beam TC
Facial Scans 3D	Facial Scans 3D
Oral Scans	Oral Scans
Rx Orthopantomographic (Optional)	Rx Orthopantomographic (not requested)
Rx Telecranium AP-LL (Optional)	Rx Telecranium AP-LL (not requested)
Occlusal Scans (not requested)	Occlusal Scans (Optional)

Table 3
Minimal requirement to work with the two software.

Recommended (Dolphin Imaging)	Minimum (Dolphin Imaging)	Component	Minimum (IPS)	Recommended (IPS)
Windows 7 SP1, Windows 8, Windows 8.1, or Windows 10	Windows 7 SP1, 32 or 64 bit	**Operating System**	Windows 7,8, 10 64 bit	Mac OS Yosemite or Higher
4GB or higher	2GB (4GB for Dolphin 3D)	**RAM**	8GB	16GB
Intel® Core™ i7	Intel® Core™2 Duo	**CPU**	2 core processor	i7 Processor with high clock rate
3D only: 512MB video card, based on one of these DirectX 9.0 graphics engines or better: NVIDIA 8400 GS, ATI HD 5450, or Intel HD 4600	Standard (not mentioned)	**Graphics Card**	Optimal 3D support (Open GL)	Min 1 GB own onboard memory, 2GB for 4K/Retina displays
1920x1080	1280x1024 at 24-bit color	**Screen Resolution**	1440x900	Full HD (1920 x 1080), 1920 x 1200
500GB or higher	3 GB free disc space only to install,	**Disk Space**	5 GB free disc space or more	
Broadband connection of 5Mbps or faster	Broadband connection	**Internet**	Internet Connection	Broadband Internet Connection

Figures

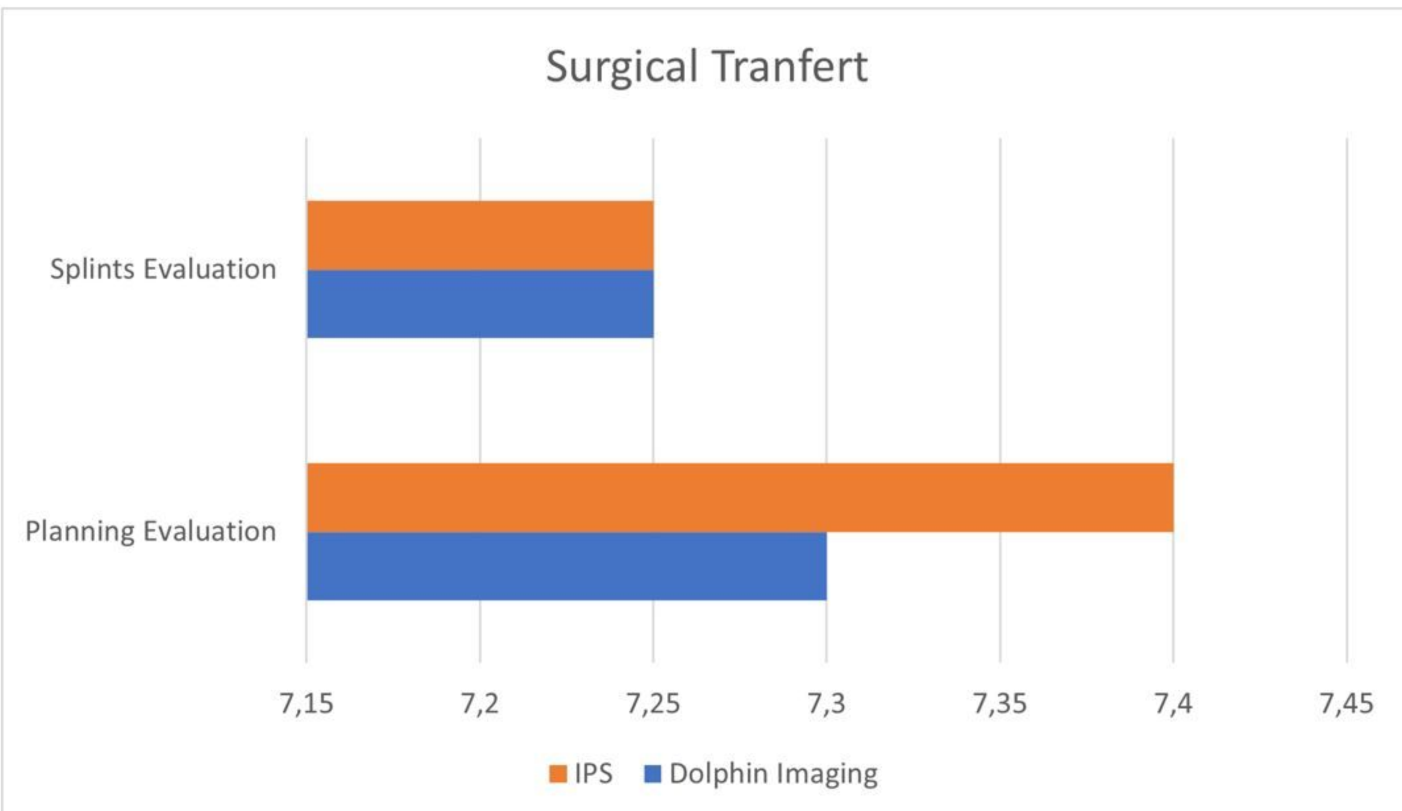

Figure 1

Evaluation of the surgical transfert