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PhD THESIS

CLINICAL AND EXPERIMENTAL ASPECTS OF DIGITAL IMPRESSIONS

SUMMARY

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SUMMARY

The main objective of this manuscript was to observe the limitations of digital impression, both in the most common and in particular clinical scenarios, with the hope of obtaining a series of answers regarding the indications and benefits of intraoral scanning. Also another objective of this thesis was to evaluate the clinical performance of intraoral scanning systems, to see if the parameters of operation and use indicated by the manufacturers, correspond to the practical application of these systems.

The evaluation of intraoral scanning systems, more precisely of digital impressions, starts from a requirement found in the case of conventional impression, respectively the accuracy of recorded surfaces. The studies carried out in the present doctoral thesis tried to evaluate these characteristics by simulating various clinical scenarios, in which the comparative evaluation of traditional and digital impression techniques was performed.

In the last decade, the technology has developed at an extremely fast pace, encompassing all aspects of daily life, from mobile phones, which have become increasingly efficient, to homes and smart cars, which increasingly predict the needs of the users. In this context, the transition from conventional methods of treatment, time consuming and subject to various errors, to digital ones, has become inevitable. Digital technologies have profoundly marked most dental specialties. Dental prosthetics has enjoyed the most obvious improvements in the digital operational flow, focused on the use of digital impression techniques and CAD / CAM systems.

Nowadays, intraoral scanners have become more and more present in dental offices. The main reasons for this success are the reduction of working time for the clinician, increased comfort for the patient, real-time visualization of the quality of treatment and the possibility of making corrections if necessary, without repeating all previous work steps.

However, there are also some limitations of these systems. First, the learning curve is not as easy as one may think, which is why not every clinician can successfully use such a system from the very beginning. Also, not all cases are suitable for intraoral scanning techniques. Restrictions on improper preparation geometry, poor isolation, difficult access to the scan tip in certain areas, and high purchase prices are still obstacles to a complete shift from conventional to digital impressions.

Given the growing number of scanning systems available on the market, an extremely valid question arises for a clinician: " Which of all these systems should I choose, so as to make my work easier but at the same time maintain the quality of the treatments? ". The answer to this question is not easy at all and can change from one year to another, due to the rapid evolution of these technologies. In most cases, the most important features taken into account when choosing an intraoral scanning device are accuracy, data recording speed, ergonomics and the ability to send the scanned data to a dental laboratory, respectively to be an open system that allows you to export STL files.

For an intraoral scanning system to be used successfully, its accuracy must be below 50 μm. For a single-tooth prosthetic restoration, this value is considered to be high, while for a multi-element restoration, an accuracy of 50 μm or even higher is considered clinically acceptable.

The larger the area to be scanned, the lower the accuracy, due to the data recording algorithms, which practically 'weave' the captured images, one after the other. Scanning a larger area (ie the entire arch) increases the risk of errors. Also, repeated scanning of an area will increase the number of possible errors.

Standards for determining the scanning accuracy of intraoral systems are not well defined. There are numerous studies that test various *in vitro* scanning systems, many of which are not clinically relevant, because the margins of trueness and precision between which these systems operate are more or less at the discretion of the manufacturing companies.

The main scientific objectives of this research are:

1. Assessing how the geometry of a dental preparation influences the accuracy of the digital impression compared to the conventional impression

2. Evaluation of the impact of clinical factors (presence of teeth adjacent to the prepared dental abutment) on the trueness of an intraoral scan

3. Comparative assessment of the accuracy of recording the details of a preparation between different intraoral scanning systems

4. Evaluation of the acceptability of digital techniques by dentists

5. Appreciation of the benefits of digital impressions in assessing the parameters of a dental preparation

6. Evaluation of the marginal adaptation of all-ceramic crowns manufactured by CAD /CAM technology obtained by direct and indirect digital workflow

7. Evaluation of the clinical applicability of digital technologies in prosthetic restorative treatment.

The first study evaluated the influence of the geometry of dental preparations (abutments) on the accuracy of both conventional and digital impression methods. A series of central maxillary incisors made of resin were prepared for all-ceramic crowns with angles of 0^0, 5^0, 15^0 and 25^0, preparations were scanned using an intraoral scanner as well as a laboratory scanner. Then conventional impressions were made with polyvinyl siloxane (PVS), obtaining three models for each reference abutment. By overlapping the .STL files, the deviation patterns of the scans from the tested groups were observed and compared to the reference model.

In **the second study**, the influence of the dental structures adjacent to the preparation on the fidelity of the intraoral scan was evaluated. A maxillary premolar was prepared for a single tooth ceramic prosthetic restoration, being then scanned in three simulated clinical situations: no tooth adjacent to the preparation, one tooth adjacent to the preparation and both adjacent teeth, absent. The comparison of the files was done using an overlapping algorithm in the program. The result was in the form of color maps indicating the differences in 'matching' between scans.

The third study analyzed the accuracy (trueness and precision) of two intraoral scanning systems, for an onlay-type preparation. Two intraoral scanners, PlanScan and CEREC Omnicam, were used, as well as a high-resolution laboratory scanner, D700. A standard first maxillary molar of resin was prepared for a ceramic onlay and then scanned with both scanners as well as the laboratory scanner (reference model). Trueness values were obtained by overlapping the STL files in the test groups with the STL file of the reference scan. The overlap of the STLs within each test group generated the values for precision.

The fourth study investigated the efficiency and perception of operators regarding the two impression techniques, conventional and digital. Five dentists, five prosthodontics resident and four students, made digital and conventional impressions for an FPD, on a typodont mounted on a mannequin. The effectiveness of the impression technique was evaluated by measuring the total working time, which also included the preparatory steps for the actual work. Operators were asked to complete a questionnaire regarding the two impression methods, and the responses were quantified.

The fifth study investigated the prevalence of errors in the geometry of the preparations, which went unnoticed by prosthodontics residents and to determine whether they could have been identified and corrected following the analysis of the digital model. 60 abutments prepared by 30 prosthodontics residents were analyzed. Each abutment was scanned using an intraoral scanner (PlanScan, Planmeca) and introduced into the Romexis software where the occlusal reduction, occlusal convergence of the axial walls, the width and homogeneity of the finish line, as well as the negative angles were analyzed.

The sixth study investigated the marginal fit of crowns manufactured by CAD / CAM technology resulting from direct and indirect scanning of a prepared abutment. Four digital impressions were made, using the Planscan intraoral scanner (Planmeca) by directly scanning the abutment fixed in the typodont, thus resulting the digital models. A number of eight conventional impressions were then made using two different types of impression materials. The resulting casts were scanned with the same intraoral scanner being introduced in the Romexis CAD / CAM software, then following the same protocol as the directly scanned group. All crowns were inspected and photographed at a magnification of 40x with the help of a digital camera (D3300, Nikkon) mounted on a stereomicroscope.

The seventh study highlighted the aesthetic and functional results obtained by combining digital and conventional methods of manufacturing prosthetic restorations. A 63-year-old patient was addressed to the Dental Prosthetics Discipline from Timișoara, with the main complaint of aesthetic problems of the frontal area as well as functional problems in the lateral arches. Intraoral examination revealed the following: gingivitis in the mandibular frontal group, old fixed prosthetic restorations in the posterior area and severe wear of the teeth of the maxillary frontals. For the maxillary frontal group, minimally invasive preparations were made, with a rounded finish line, involving four crowns on the incisors and one veneer on the canine. Due to the minimal reduction of tooth hard tissues, the vitality of the abutments could be maintained. The preparations were scanned with the PlanScan intraoral scanner, the ceramic restorations (Empress CAD Multi), being milled in the office (Planmill 40, Planmeca). The ceramic restorations were bonded following an adhesive cementation protocol, with a light-curable cement.

The final conclusions of the present thesis are presented below.

Regarding the way in which the final angulation of a preparation influences the final result of the impression it was observed that:

1. Both groups investigated (conventional PVS impression and digital impression) showed an increase in accuracy at an occlusal convergence of the abutment of 15^0.

2. At the occlusal convergence close to 0^0, both groups showed similar values of accuracy.

3. For both groups investigated, the mean trueness values indicated that the digital impression group had the lowest deviation from the reference model.

The investigation regarding the effect of the clinical factors represented by the presence of teeth adjacent to a preparation, on the trueness of the digital impression, led to the following conclusions:

4. The the trueness of the digital impression is conditioned by a good visibility of the preparation.

5. The presence of adjacent teeth reduces interproximal visibility, with a minus of data at this level.

6. The lowest trueness was found in the presence of both teeth adjacent to the preparation, for all operators, followed by the scenario with a single adjacent tooth without any mesial and distal neighbouring teeth.

7. The influence of the operators and the individual scanning patterns, in the occurrence of digital impressions errors, did not show statistical significance.

The comparative investigation between the accuracy of the digital impressions obtained with two scanning systems, CEREC Omnicam and Planmeca PlanScan, in the simulated scenario for an onlay type restoration, highlighted the following:

8. The accuracy deviations of the two scanners analyzed were consistent, with no major differences between them.

9. Although a number of discrepancies could be observed during the visual inspection of the 3D models obtained with the two scanners, they were not statistically significant.

Dentists' perceptions of digital impressions and the use of the intraoral scanning technique, as well as the time allocated for the two impression techniques (conventional and digital) were also assessed, drawing the following conclusions:

10. The average working times within the group of specialists were statistically significantly different between the conventional and the digital method.

11. In both the resident and the student group, the differences between the recorded working times for the two methods were significant.

12. The average working time for the conventional impression was the lowest for the group of specialist doctors, followed by the group of residents and students. However, the results were not statistically significant.

13. For the digital impression, the shortest working times were highlighted in the group of resident doctors, followed by the group of students and specialists. In this situation as well, the results were not statistically significant.

14. 63.3% of the study participants stated that the preferred technique was the digital impression, 28.6% of the participants had no preference, and 7.10% preferred the conventional impression technique.

15. 92.9% of the participants considered that the digital impression allows for an increase in efficiency in the office, while 7.1% of the participants chose the conventional impression.

16. 78.6% of the study participants considered that digital impression creates the premises for superior clinical results, while 21.4% considered that both techniques lead to qualitative clinical results.

17. Conventional impression was less efficient than digital impression. The average working times were shorter for the digital impression, thus confirming the null hypothesis.

The study regarding the evaluation of abutment preparation errors, as well as the benefits of using the digital impression as a tool to evaluate the parameters of a preparation, led to the conclusions listed below:

18. More than half of the operators did not meet the requirements of occlusal clearance. Regarding the reduction proximal, only 26.6% of preparations met the initial specifications.

19. The optimal width of the finish line was observed in 16.6% of cases, while the homogeneity of the finish line was present in 47% of the abutments examined. The ideal occlusal convergence angles were present in 36% of the preparations.

20. Digital impression allows an immediate evaluation of the geometry of the preparation, which can be a tool for objective evaluation of dental preparations.

The comparative study between the direct and indirect scanning protocol for obtaining ceramic restorations with CAD / CAM technology presented the following conclusions:

21. Both direct and indirect digital methods of performing CAD / CAM FPD lead to clinically acceptable marginal fit values.

22. The direct digital method is more efficient in terms of working time, requiring fewer steps.

The combination of digital and conventional methods in the treatment of severe dental wear in the frontal area, in patients with associated pathologies (type 2 diabetes) had as conclusions:

23. The combination of restorations made with CAD / CAM technology, as well as those made by the conventional method (in the dental laboratory), lead to prosthetic treatments that satisfy both aesthetic and functional requirements.

24. Proper occlusal balance is all the more important in patients with associated metabolic diseases due to the major influence they have on the supporting structures of the teeth.

The doctoral thesis carried out multidirectional research, and the *in vitro* and *in vivo* studies performed tried to contribute to the clarification of some controversial aspects found in the specialized literature regarding the digital impressions. Through the investigated scenarios, a series of questions were clarified, but at the same time there are still many unknowns that need to be solved.

Due to the constant evolution of technologies and equipment, it is necessary to continue the research related to this innovative field of intraoral scanning, with a major importance in the digital operational flow. Subsequent studies will focus on researching scanning technologies with ultrasonic technology to obtain high-resolution intraoral images. The ultimate goal is to increase clinical efficiency and create the possibility to obtain accurate digital impressions, which will allow the realization of aesthetic, functional and long-lived prosthetic restorations.