Experimental and Clinical Results to Support Workflows in Implant Dentistry

Summary of the PhD thesis

by

DR. HENRIETTE LERNER, DDS

Supervisor:

PROF. KATALIN NAGY, DDS, PhD, DSc

University of Szeged, Faculty of Dentistry, Department of Oral Surgery

Szeged, 2021

PUBLICATIONS PROVIDING THE BASIS OF THE THESIS

1. Mangano, F.G., Admakin, O., Bonacina, M. et al. Trueness of 12 intraoral scanners in the full-arch implant impression: a comparative in vitro study. BMC Oral Health 2020. 20:63 https://doi.org/10.1186/s12903-020-01254-9

IF: 2.13

2. Imburgia M, Kois J, Marino E, Lerner H, Mangano FG. Continuous Scan Strategy (CSS): A Novel Technique to Improve the Accuracy of Intraoral Digital Impressions. Eur J Prosthodont Restor Dent., 2020. 31;28(3):128-141. doi: 10.1922/EJPRD_2105Imburgia14.

IF: 0.81

3. Lerner H, Mouhyi J, Admakin O, Mangano F. Artificial intelligence in fixed Implant Prosthodontics: a retrospective study of 106 implant-supported monolithic zirconia crowns inserted in the posterior jaws of 90 patients. BMC Oral Health, 2020. 19;20(1):80. doi: 10.1186/s12903-020-1062-4.

IF:2.13

4. Lerner H, Hauschild U, Sader R, Ghanaati S. Complete-arch fixed reconstruction by means of guided surgery and immediate loading: a retrospective clinical study on 12 patients with 1 year of follow-up. BMC Oral Health, 2020. 16;20(1):15. doi: 10.1186/s12903-019-0941-z.

IF: 2.13

Summed impact factor: 6.954

I. INTRODUCTION

Digital technologies have revolutionized the world of dentistry. Not only intratoral scanning and digital surgical planning have entered the scene, but also artificial intelligence. Intraoral scanners and digital surgical planning are especially becoming widespread. While these technologies indeed offer new vistas in dentistry, sometimes it is still a question how best to use them in the everyday dental practice. Artificial intelligence for dentistry, it may be said, is still in the phase when validation studies are needed.

This thesis deals with a few problems regarding the use of digital technologies in the workflow of digital implant dentistry. The thesis is based on four studies. The first of these deals with the accuracy of intraoral scanning for full-arch restorations and proposes a specific approach to improve that accuracy. The second study addresses the problem of potential intraoral scanning inaccuracies when working with long-span restorations. This study demonstrates a specific technique to reduce these inaccuracies. The third study looks at the possibility of utilizing a fully digital workflow involving artificial intelligence to fabricate implant-supported, monolithic zirconia crowns to be cemented onto customized hybrid abutments. The fourth study describes experience with a fully digital guided workflow for full-arch restorations. The shared aim of these studies was to offer further evidence-based recommendations to the everyday practice.

II. OBJECTIVES AND HYPOPTHESES

1. To date, the scientific literature in fixed implant prosthodontics has validated the use of IOSs for capturing optical impressions when designing and manufacturing short span restorations, such as single crowns (SCs) and partial prostheses (PPs). However, several studies and reviews of the literature have reported that with long-span and full-arch restorations (FAs), IOSs do not yet demonstrate sufficient accuracy. The purpose of the *in vitro* study regarding IOSs was to assess and compare the overall trueness of 12 different commercially available IOSs with full arch rehabilitations, using two different investigation methods: mesh-to-mesh and nurbs-to-nurbs superimposition We hypothesized that the nurbs-to-nurbs approach would improve the accuracy of IOS scans in full-arch cases.

2. Several in vitro and in vivo studies have demonstrated that IOSs represent an accurate and reliable solution when taking optical impressions of partially edentulous patients to fabricate short-span restorations. Other studies have reported a persistent accuracy problem with intraoral scanning when long-span prosthetic restorations are fabricated. The second study covered in this thesis tested if a novel scanning strategy, called the "continuous scanning strategy" (CSS) could address this problem. The hypothesis was that in fully edentulous patients, due to a lack of anatomic reference points, it is more difficult to obtain accuracy when an IOS reads the distance between different scan bodies that sit at different heights away from

the soft tissues. The hypothesis was that CSS would efficiently address this problem.

3. The purpose of the third (retrospective) study of the thesis was to present a protocol to demonstrate the advantages of using AI within a full digital workflow when fabricating implant-supported, monolithic zirconia crowns (MZCs) to be cemented onto customized hybrid abutments. It was hypothesized that an entirely digital workflow involving AI could be efficiently used in for restorations involving single implants and customized hybrid abutments with monolithic zirconia crowns.

4. Guided implant surgery is considered safe and minimally invasive when performed as a flapless procedure. However, flapless guided surgery with implants placed into post-extraction sockets, which are then immediately loaded with complete-arch fixed provisionals without artificial gingiva, has not yet been thoroughly evaluated. As such, questions remain as to whether these types of immediate loaded complete-arch fixed reconstructions can offer both successful implant treatment and esthetic outcomes. Therefore, the fourth study of the thesis aimed to present the outcomes of guided flapless implant placement surgeries, where the implants were immediately functionally loaded with complete-arch fixed prostheses absent of artificial gingiva. This study sought to verify the use of a fully digital workflow for FA restorations. The hypothesis was that the short-term results would not be inferior to those achievable with more conventional approaches, either esthetically or functionally.

III. RESULTS

The key results of the studies are summarized as follows:[1]

1. The calculated nurbs-nurbs errors were systematically lower than the mesh-mesh errors. Statistically significant differences were found between the different IOSs.

2. In the studied period, 40 eligible patients were restored with 45 long-span implant-supported restorations (10 fixed PPs supported by ≥ 4 implants, and 35 FAs supported by 6 to 8 implants), fabricated with a complete digital workflow that began with the CSS technique. The primary outcome of this study was the superstructures' passive fit and marginal closure quality recorded at 2 time points: Time 0 (T0) when the CAD-designed superstructure was tested with a milled polyurethane or metallic replica and Time 1 (T1) when final monolithic zirconia restoration was delivered. At T0, 40 out of 45 replicas demonstrated ideal marginal adaptation and passive fit. At T1, all final monolithic zirconia restorations demonstrated passive fit and excellent marginal adaptation, except for one that exhibited minimal friction and fractured minutes after being screwed to place. The secondary outcomes of the study were the survival of the implants and the success of the prostheses. These outcomes were assessed 2 years after delivery of the final prostheses (time 2 = T2). At T2, the

[1] The numbering follows the numbering of the studies as given under Objectives and Hypotheses.

implant success rate was high (100%), with all implants in function.
At the end of the study, 42 of the 45 final zirconia prostheses (93.3%) were considered suc-cessful because they functioned without any complications over the two-year observation period. The incidence of prosthetic complications was 6.7%.

3. 90 patients were included in this retrospective study, whose missing teeth were restored with 106 implant-supported Monolithic Zirconia Crowns (MZCs) on 106 individual customized abutments. Both the qualitative and quantitative results were favorable, showing the potential that a full digital workflow involving AI has in this indication. The MZCs demonstrated high-quality marginal adaptation, interproximal and occlusal contacts, and esthetic integration. Importantly, during the period of study observation and the follow-up (0-36 months), few biologic (1.9%) and few prosthetic (5.7%) complications affected the implant-supported MZCs. Accordingly, high survival and success rates were found (>90%).

4. In the reviewed period, 12 patients received 110 implants (65 of these were post-extraction). At the end of the provisionalization period, 72 fixed zirconia-ceramic prosthetic restorations (53 single crowns, 17 bridges, and 2 fixed full arches) were delivered. The 1-year implant survival rate turned out to be 98.2%, with 108 out of 110 total implants surviving. The surviving implants also demonstrated good soft tissue stability. Only 1 patient of

the 12 experienced implant failure, resulting in a 1-year patient-level survival rate of 91.7%. 8/12 prostheses (66%) did not undergo any failure or complication during the entire follow-up period. At the 1-year follow-up control, the soft tissue was stable in all patients and the esthetic results were satisfactory.

IV. CONCLUSIONS

The thesis brought the following novel results:

1. It has been demonstrated that the accuracy of intraoral scanning for full-arch restorations can be improved by using the nurbs-to-nurbs method, instead of the mesh-to-mesh method.

2. It has been demonstrated that the quality of intraoral scanning for full-arch restorations can be improved by applying the continuous scan strategy, by eliminating the scanning jumps that normally stem from level differences in the scanned area.

3. It has been demonstrated that an entirely digital workflow involving AI can be efficiently used in for restorations involving single implants and customized hybrid abutments with monolithic zirconia crowns and that the short-term clinical outcomes associated with the said approach are favorable.

4. It has been demonstrated that full-arch fixed implant reconstruction employing guided surgery placing implants into fresh extraction sockets followed by immediate loading is a safe, reliable and successful approach in the short term. The short-term outcomes achieved with this approach are not inferior to those achievable with more conventional approaches, either esthetically or functionally.

V. ACKNOWLEDGEMENTS

Throughout the writing of this dissertation, I have received a great deal of support and assistance.

I wish to warmly thank You, my supervisor, Professor Katalin Nagy, former dean of the Faculty of Dentistry, and Head of the Department of Oral Surgery at the University of Szeged, for your patient trust, support and for all the opportunities you have given to me. You provided me with the tools that I needed to choose the right direction and complete my dissertation.

I thank You, Dr. Gábor Braunitzer, for your excellent advice. Your insightful feedback pushed me to sharpen my thinking and brought my work to a higher level.

I am deeply thankful to You, Professor Francesco Mangano for your continuous support and help in my research activities.

I am also grateful to Dr. Robert Kerstein for his assistance with the English editing of this thesis.