PROSTHODONTIC APPLICATION OF INTRAORAL SCANNING SYSTEMS

Ph.D. Thesis Booklet

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Budapest

2025

1. Introduction

1.1. What is the topic?

The topic is the prosthodontic application of intraoral scanning systems, focusing on their complete-arch accuracy and the additional feature of tooth shade determination.

1.2. What is the problem to solve?

Dentistry is digitalizing, and the modern digital workflow begins with intraoral scanning. The number of new intraoral scanners (IOSs) introduced in the market is proliferating; however, scientific knowledge and evidence often need to be improved, and the changes cannot be followed as quickly as rapid advancements. The biggest expectation against IOSs is accuracy, as, without an accurate impression, the fabrication of orthodontic appliances and prostheses is impossible. IOSs are not just impression machines; they also have additional features that can be used during the workflows. These devices can even determine the tooth color, essential for achieving an aesthetic result. While the literature agrees that visual and

digital methods should be used for accurate color determination, if an IOS can accurately define the tooth color, there may be no need for a separate digital tool. The accuracy of this feature still needs to be investigated.

1.3. What is the importance of the topic?

Most dental prostheses are manufactured with Computer-aided design/computer-aided manufacturing (CAD/CAM) technology, where digital data generated from the upper and lower jaw is used to design the restoration digitally. Digital data can be generated by laboratory scanners or by IOSs. IOS can make the digital workflow and patient treatment faster and easier. One of the most critical factors determining patient satisfaction is tooth color. Due to human vision, the visual method is subjective and unreliable, so both digital and visual methods should be used together. If the scanner is capable of digital determination, there is no need to invest in a separate device or require additional time to determine the tooth color.

1.4. What would be the impact of our research results?

Our research aims to assist dentists in effectively using IOSs, particularly for prosthodontic procedures. We seek to determine whether they are fully equipped for all types of digital prosthetic treatments or if there are limitations in their usage. The accuracy of these devices is a critical factor. While they are considered sufficiently accurate for single restorations, the accuracy for full-arch scans remains uncertain, with both acceptable and unacceptable results reported in both clinical practice and the literature. Besides accuracy, manufacturers often try to convince dentists to purchase their products by offering special features such as caries detection, smile design, patient-specific movements, and shade selection. If these features are accurate and valuable, they can help make the treatment process more effective. However, if their performance is lacking, dentists should be cautious and recognize that such claims may be more about marketing than evidence-based dentistry.

2. Objectives

2.1. Study I. – Evaluation of the accuracy of intraoral scanners for complete-arch scanning

This network meta-analysis (NMA) aimed to investigate the accuracy, precision, and trueness of complete-arch intraoral scanning with different IOSs to that of reference Standard Tesselation Language (STL) files and to provide dentists with guidance on choosing the suitable device for complete-arch scanning through an NMA.

1. The first null hypothesis is that there was no statistical difference between the IOS STL scans and the reference STL scans.
2. The second null hypothesis is that there was no statistically significant difference in IOS devices' accuracy (precision and trueness).
3. Thirdly, we hypothesized that the accuracy of the 95% confidence interval (CI) of the IOSs was within the clinically acceptable threshold of 120 μm.

2.2. Study II.- Color comparison between intraoral scanner and spectrophotometer shade matching

This systematic review and meta-analysis aimed to compare IOSs' accuracy, trueness, and precision (repeatability) to spectrophotometers (SPs) in determining tooth shade.

The research hypothesis is that there was no significant difference in the accuracy of shade selection between IOSs and SPs.

1. The null hypothesis is that there was no significant difference in shade selection between IOSs and SPs when trueness was expressed in match percentages.
2. The alternative hypothesis was that the repeatability of IOSs is high with a clinically acceptable match percentage.

3. Methods

3.1. Study I. - Evaluation of the accuracy of intraoral scanners for complete-arch scanning

Data: This study included publications comparing the accuracy of IOS STL files with reference STL scans across various arch types, including dentate, edentulous, completely edentulous with implants, and partially edentulous with implants.

Sources: An electronic search of five databases, limited to English-language studies, was conducted in October 2021.

Study Selection: A total of 3,815 studies were identified, with 114 meeting the inclusion criteria. After selecting the studies and extracting the data, pair-wise comparisons and a NMA were performed to evaluate scanning accuracy across the four arch subgroups using four outcomes: trueness and precision, measured as mean absolute deviation and root mean square values. The risk of bias was assessed using Cochrane guidelines and the

QUADAS-2 tool, while the GRADE system was applied to assess the certainty of the evidence.

3.2. Study II. - Color comparison between intraoral scanner and spectrophotometer shade matching

Data: This study included publications comparing the shade determination accuracy of IOS compared to (SP).

Sources: An electronic search was conducted on October 19, 2023, across five databases (PubMed, Scopus, Embase, Web of Science, CENTRAL).

Study selection: This search yielded 163 studies, of which 23 met the eligibility criteria for inclusion. The studies consisted of in vivo and in vitro quasi-experimental designs. After extracting the data, a quantitative analysis was performed to assess the accuracy of IOSs across different subgroups, using four outcomes: trueness and precision at various measurement sites. A random-effects model was applied to combine effect sizes, with the pooled proportion and a 95% CI used to measure the effect size.

4. Results

4.1. Study I. - Evaluation of the accuracy of intraoral scanners for complete-arch scanning

Considering both trueness and precision, the accuracy of the IOSs did not show significant differences when compared to the reference scans in dentate arches (three IOSs), edentulous arches (three IOSs), and fully edentulous arches with implants (one IOS). However, for partially edentulous arches, the accuracy of all IOSs differed significantly. There were notable differences between the IOSs themselves.

Out of the 18 IOSs tested for accuracy in dentate arches (MAD), only four (CEREC Primescan, 3Shape Trios 3, Medit i500, Cadent iTero) demonstrated clinically acceptable accuracy, with the CI for trueness and precision below 120 µm. Only one of the nine IOSs (CEREC Primescan) met clinically acceptable accuracy in edentulous arches. For completely edentulous arches with implants, only one of the 12 IOSs (3Shape Trios 2) was clinically acceptable. No IOSs were clinically acceptable for partially edentulous arches.

4.2. Study II - Color comparison between intraoral scanner and spectrophotometer shade matching

A total of six articles were included in the statistical analysis of the trueness outcome, as represented by the 3D Master shade guide system (3D). The average trueness of IOSs was found to be clinically significant at 0.38 (CI: 0.24–0.53), with a statistically significant difference (p < 0.001). The average trueness for the 3Shape Trios 3 subgroup was 0.4 (CI: 0.24–0.59).

Three studies were included in the statistical analysis of the trueness outcome, which was measured using the Vita Classical shade guide system (VC). The average trueness of IOSs was found to be clinically significant at 0.28 (CI: 0.09–0.60), with a statistically significant difference (p < 0.001).

Six articles were included in the statistical analysis of the repeatability results, which were assessed using the 3D shade guide system and measured at the middle third of the reference teeth. The average trueness of the IOSs was 0.85 (CI: 0.74–0.92), showing a statistically significant difference (p < 0.001).

Three studies were part of the statistical analysis for the repeatability outcome, which was evaluated using the 3D shade guide system at the cervical, middle, and incisal third of the reference teeth. The average trueness of the IOSs was clinically acceptable at 0.73 (CI: 0.59–0.84), with no statistically significant difference ($p < 0.070$).

Three studies were incorporated into the statistical analysis of the repeatability results for the VC system using the 3Shape Trios 3. The average trueness of the IOSs was clinically acceptable, measuring 0.81 (CI: 0.64–0.91), with a statistically significant difference ($p < 0.001$).

5. Conclusions

5.1. Study I. - Evaluation of the accuracy of intraoral scanners for complete-arch scanning

1. Statistically significant differences were found between IOS STL scans and the reference STL scans (precision and trueness).
2. Statistically significant differences were found between the various IOS devices' accuracy (precision and trueness).
3. Additionally, the accuracy of the 95% CI of some IOSs was within the clinically acceptable threshold of 120 μm.

In conclusion, with some exceptions, IOS systems are sufficiently accurate for generating clinically acceptable complete-arch digital impressions. The accuracy of IOSs for complete arches can differ under various clinical scenarios. IOSs do not provide accurate complete-arch digital impressions in cases with implants. The newer generation IOSs are not always the most accurate devices, but there is a visible tendency for an increase in accuracy over time with advances in IOS technology.

5.2. Study I. - Color comparison between intraoral scanner and spectrophotometer shade matching

There was a significant difference in the accuracy of shade selection between IOSs and SPs.

1. There was a significant difference in shade selection between IOSs and SPs when trueness was expressed in match percentages.
2. The repeatability of IOSs is high, with a clinically acceptable match percentage.

In conclusion the trueness of shade matching with IOSs is low compared to SPs, although the precision is considered high and is similar to SPs. The low trueness made the accuracy of IOSs unacceptable compared to SPs.

6. Bibliography

Publications related to the thesis

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