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UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES
POSTGRADUATE DENTAL COLLEGE
NAVAL POSTGRADUATE DENTAL SCHOOL
8955 WOOD ROAD
BETHESDA, MARYLAND 20889

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Name of Candidate: Danielle M. Marquis
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6/4/21

Christopher M. Hamlin
PROSTHODONTICS DEPARTMENT, NAVAL POSTGRADUATE DENTAL SCHOOL
Committee Chairperson

6/8/21

Stacy L. Yu
PROSTHODONTICS DEPARTMENT, NAVAL POSTGRADUATE DENTAL SCHOOL
Committee Member

6/4/21

Nicholas J. Hamlin
RESEARCH DEPARTMENT, NAVAL POSTGRADUATE DENTAL SCHOOL
Committee Member

TIME-DEPENDENT DIMENSIONAL STABILITY OF PERI-IMPLANT SOFT TISSUES DURING IMPRESSION MAKING

by

Danielle M. Marquis,
LCDR, Dental Corps
United States Navy

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ABSTRACT

Time-Dependent Dimensional Stability of Peri-implant Soft Tissues During Impression Making

Danielle M. Marquis, DDS

Thesis directed by: CAPT Christopher Hamlin, Chairman, Prosthodontics Department

Abstract: Peri-implant soft tissue is often sculpted to develop ideal emergence profile by use of a provisional restoration. However, this tissue has been shown to collapse upon removal of the provisional restoration. If the tissue remains collapsed during impression-making, the effect could be a final restoration designed with a cementation margin more subgingival than intended, compromising removal of residual cement, a risk factor for peri-implantitis and implant failure. It is currently unknown whether peri-implant soft tissue remains in this collapsed position upon placement of a custom impression coping for final impression. The objective of this observational study is to determine whether peri-implant soft tissue, sculpted by means of a provisional restoration, immediately returns to its original position following removal and replacement of the provisional restoration. Ten subjects will be enrolled in this study. An intraoral scanner (3Shape TRIOS) will be used to capture the vertical position of the soft tissue at three different time points for each sculpted implant site: 1) prior to removal of the provisional restoration, 2) twenty minutes after removal, and 3) immediately

following provisional replacement. Standard tessellation files of each scan will be superimposed using 3D analysis software (Materialise 3-matic). The soft tissue position will be marked at four locations: mid-facial, mid-palatal, and the peaks of the mesial and distal papillae. Scans 1 and 2 will be compared to confirm tissue collapse. Scans 1 and 3 will be compared to observe whether the tissue remains collapsed or returns to its original position. Statistical analysis will evaluate the observed changes in vertical position for significance. Final approvals to begin research are being obtained. Subject recruitment will be ongoing, with final results anticipated in the next 12-18 months.

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LIST OF ABBREVIATONS

IRB	Institutional Review Board
mm	millimeter(s)
STL	Standard Tessellation Language
WRNMMC	Walter Reed National Military Medical Center

CHAPTER 1: Introduction

CEMENTATION MARGIN LOCATION

Residual cement at the cementation margin has been identified as a risk factor for peri-implantitis and peri-implant mucositis.[1, 2] The apical-coronal position of the cementation margin plays an essential role in the clinician's ability to detect and remove residual cement. The deeper the margin is positioned subgingivally, the more likely cement will be undetected. To meet esthetic needs while facilitating cement removal, an ideal cementation margin would be at the gingival margin when esthetics permit or no more than 1 mm subgingival to it.[3] Fabrication of an abutment that meets these criteria requires an impression that captures the exact apical-coronal position of the gingival margin as it rests against the provisional restoration.

PERI-IMPLANT SOFT TISSUE DEVELOPMENT

Shaping of peri-implant soft tissues is routinely used to develop the subgingival emergence profile for optimal esthetics and peri-implant health.[4, 5] Soft tissue-shaping is typically accomplished using an implant-supported fixed provisional restoration.[6, 7] This practice is common in the esthetic zone, which for most patients extends from maxillary first molar to first molar.[8] Clinicians who advocate for this approach recommend a development interval of one to three months. This achieves a stable gingival position prior to impressing and fabricating a definitive abutment and restoration.[9-11] Establishing a stable gingival margin position is particularly critical when planning an implant-supported cement-retained restoration. Careful planning of the apical-coronal position of the abutment cementation margin is important not only to prevent unesthetic visibility of

the abutment but also to facilitate removal of excess cement upon delivery of the final restoration.

CAPTURING THE SOFT TISSUE POSITION

To capture an accurate impression of peri-implant soft tissues around a site developed through use of a provisional restoration, the soft tissue position ideally would remain static during the impression-making process. In reality, peri-implant soft tissues collapse upon removal of the provisional restoration.[12, 13] Li et al.[13] demonstrated that the magnitude of the collapse in an apico-coronal dimension was near zero immediately upon removal. However, this increased to a maximum of 0.15 mm at the mid-facial and 0.27 mm at the mesial and distal papillae after 20 minutes. These measurements were statistically significant relative to a baseline measurement taken prior to removal of the provisional restoration. The authors postulate that removal of the transmucosal element reduces pressure on the peri-implant soft tissue. The low osmotic pressure of the tissue then results in an inflow of interstitial fluid, causing a thickening and flattening of the tissue.

This problem has been addressed by fabrication of a custom impression coping with the same soft tissue contours as the provisional restoration[14, 15] or by using the provisional restoration itself as an impression coping.[16] In a digital workflow utilizing an intraoral scanner for impression-making, similar solutions include use of a custom scan body[17] or scanning the tissue surface of the provisional restoration[18]. While these methods allow accurate reproduction of the tissue surface of the provisional restoration, they may not accurately capture the position of the gingival crest. These methods assume

that upon placement of the custom impression coping, the tissue immediately returns to its original position with the provisional restoration in place.

An analog custom impression coping typically takes about 20 minutes to fabricate. The clinician places the impression coping and makes the impression immediately afterward. If the peri-implant soft tissue does not immediately return to its original position upon placing the custom coping, the dimensional changes that Li et al. described may be clinically significant. Due to the thickening and flattening of the tissue, the clinician likely would be capturing a gingival position more apical to the final position after delivery of the definitive restoration. This would result in the clinician designing a marginal position more subgingival than he or she intended, which would compromise cement removal and risk long-term soft tissue health around the implant.

In short, soft tissue behavior following placement of an impression coping is a vital component in marginal position planning and long-term implant success, particularly in areas of high esthetic demand. As discussed previously, changes in peri-implant soft tissue without a restorative component in place have been investigated. To the author's knowledge, no published study has assessed whether the peri-implant soft tissues return to their original position following placement of a custom impression coping or replacement of the provisional restoration itself.

STUDY OBJECTIVES

The objective of this observational study is to determine whether peri-implant soft tissues, shaped for an ideal emergence profile around single-tooth implants, immediately return to their original position following removal and replacement of a provisional restoration after 20 minutes. The null hypothesis is that the soft tissues will immediately

return to their original position. The alternative hypothesis is that the soft tissues will return to a position different from their original position.

CHAPTER 2: Materials and methods

This study was approved by the Institutional Review Board (IRB) at Walter Reed National Military Medical Center (WRNMMC), IRB# WRNMMC-2021-0335. The inclusion criteria are adult patients who received maxillary single-tooth implants in the esthetic zone (first molar to first molar). Sites must be tooth-bound and undergo a minimum of eight weeks of soft tissue sculpting using a fixed implant-supported provisional restoration. Participants with active periodontal disease or systemic conditions or disorders that impair periodontal health will be excluded from the study. Written informed consent will be obtained from all participants. Determination of gingival phenotype of each subject will be recorded. All patient identifiers will be removed from the data set at the conclusion of the study.

STUDY DESIGN

An intraoral scanner (3Shape TRIOS, Copenhagen, Denmark) will be used to capture three scans for each implant site. The first scan (Scan 1) will capture the position of the peri-implant soft tissues and adjacent teeth with the provisional restoration in place. Following this scan, the provisional restoration will be removed and left out of the mouth for 20 minutes. At this time, a second scan (Scan 2) will be made of the peri-implant soft tissues and adjacent teeth. The provisional restoration will then be replaced, and a third scan (Scan 3) will be made of the peri-implant soft tissues and adjacent teeth with the provisional restoration in place (Figure 1).

In Scan 3, the provisional serves as a proxy for a custom impression coping or custom scan body. Custom copings and scan bodies require a variable amount of time to

fabricate and are not always an exact copy of the provisional or the associated soft tissue emergence profile. Therefore, using the original provisional as a proxy eliminates these two confounding variables and allows the investigation to focus on the single variable of removing and replacing the transmucosal element.

Scans will be saved as standard tessellation language (STL) files. The three STL images of each site will be superimposed using 3D visualization and analysis software (3-matic, Materialise, Plymouth, Michigan). This superimposition will be accomplished by identifying stable landmarks on the adjacent teeth. For each scan, the gingival margin position will be marked at four locations: mid-facial, mid-palatal, and at the peaks of the mesial and distal papillae. These positions will be marked in reference to a fixed point on an adjacent tooth.

For comparisons between scans, Scan 1 will serve as a baseline. The first comparison will assess the change in vertical position between Scan 2 and Scan 1. This will support the presence of soft tissue collapse as observed in previous studies. The second comparison will assess the change in vertical position between Scan 3 and Scan 1. This will test the hypothesis that the soft tissue returns to a position different from its original, sculpted position. Demonstrating a soft tissue collapse effect in the first comparison validates assessing the return of the soft tissue to its original position in the second comparison.

Demographic features of the patient study population will be tabulated and presented, including sex; age; anatomical site of implant; gingival phenotype; change in digital intraoral scan measurements (calculated as: Scan 2 – Scan 1, Scan 3 – Scan 1, and Scan 3 – Scan 2); and the direction of change (positive or negative). Multiple linear

regression will be conducted to measure if there is a significant change in vertical position of the peri-implant soft tissue between a) Scan 2 and Scan 1, and b) Scan 3 and Scan 1, with the null hypothesis being that there is no change in vertical position. Covariates will include the demographic features described above.

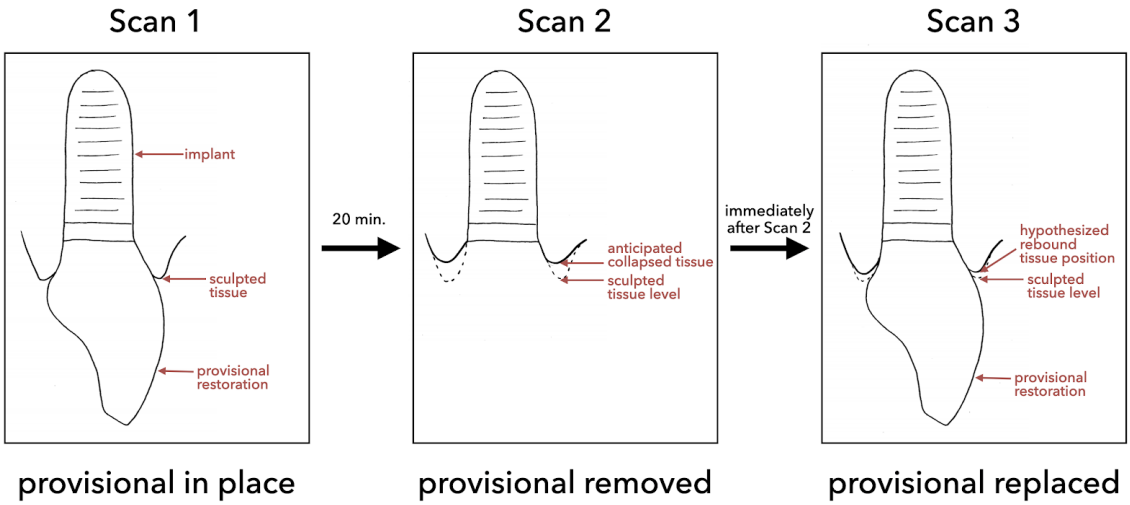

Figure 1. Schematic of intraoral scans capturing peri-implant soft tissue profile. (**Scan 1**) Intraoral scan of soft tissue developed by means of provisional restoration, prior to removal of provisional restoration. **(Scan 2)** Scan of peri-implant soft tissues 20 minutes after removal of provisional restoration. **(Scan 3)** Scan of soft tissue with provisional replaced to simulate custom impression coping, after 20 minutes of elapsed time.

CHAPTER 3: Results

This protocol is pending final approval from the WRNMMC Department of Research Programs, after which recruitment will begin. Participants will be recruited through the patient population of Naval Postgraduate Dental School. Providers will be invited to consider which of their current cases meet the inclusion criteria. Participant candidates will be invited to participate in the course of a regularly scheduled dental appointment or at a separate appointment. Enrollment and data collection is anticipated to take 18-24 months.

CHAPTER 4: Discussion

Peri-implant soft tissue collapse following removal of a provisional restoration has been documented in the literature. Duran et al.[12] observed significant differences between the emergence profile of the implant-supported restoration and that of unsupported soft tissue, with differences in soft tissue width at the mid-gingival level measuring approximately 1.3 mm. Li et al.[13] observed vertical change in peri-implant soft tissue at the gingival crest on the order of 0.15 mm mid-facial and 0.27 mm at the papillae after a provisional restoration had been removed for 20 minutes.

Restorations in the esthetic zone require contouring of the subgingival portion of the restoration to support peri-implant soft tissues in such a way that they mimic the soft tissue contours of the surrounding teeth. Since the desired soft tissue contour requires pressure from the transmucosal element, and its removal allows the soft tissue contour to change, it is not possible to accurately capture this contour with a digital impression alone. The presence of the transmucosal element will block peri-implant soft tissue from the view of the intraoral scanner.

Because of these limitations, an analog impression is required. This impression can be made in one of two ways—by fabrication of a custom impression coping or by transfer of the provisional itself into the impression. The main advantage of using a custom impression coping is shortened appointment time; the provisional restoration is returned to the patient, and the impression can be poured after the patient leaves. When the provisional restoration itself is used as the impression coping, the appointment time is lengthened since the patient must wait for the impression to be poured before the provisional restoration is replaced. However, this technique has the potential advantage

that the impression is made before the peri-implant soft tissues are disturbed. This brings up the question of whether the tissues, once disturbed, immediately return to their original position.

While the aforementioned studies showed peri-implant soft tissue collapse upon removal of a provisional restoration, they did not report on the behavior of the soft tissue when the transmucosal element is replaced. It is unknown whether the soft tissue rebounds immediately, at a later time, or if it ever rebounds completely. Each scenario would have different implications for impression-making.

If peri-implant soft tissue does not rebound immediately upon placement of a custom impression coping, this would have important clinical implications. If the soft tissue rebounds immediately upon replacement of the provisional or its proxy, then the current practice of custom impression coping fabrication is sufficient. If the tissue remains in its collapsed position during impression-making but later rebounds to its original position, the effect would be a final restoration with a cementation margin more subgingival than intended. To prevent this outcome, it may be prudent to consider using impression methods that do not allow tissue slumping to occur, such as transferring the provisional itself into the impression. When this is not feasible, an impression could be made prior to removal of the provisional to capture the tissue position as it was sculpted against the provisional for the purpose of digital abutment design.

When a screw-retained or screw-retrievable restoration is used, cementation margin location will be less significant since any cementation will be done extraorally. However, failure to capture the soft tissue in its final position can compromise the ultimate esthetic result. The soft tissue profile is altered when changes are made to the

critical and subcritical contour of the implant restoration. Critical contour, the contour directly at the gingival margin and slightly apical to it, has been shown to be of particular importance for soft tissue esthetics.[19] If the free gingival margin position is captured in a more apical position, the restoration may be designed with an under-contoured critical contour. This would cause the tissue to migrate coronally, resulting in the appearance of a short clinical crown and asymmetry with the contralateral reference tooth.

This study has several limitations. First, this study only observes maxillary implant sites from first molar to first molar, primarily for the reason that the practice of peri-implant soft tissue sculpting is most commonly carried out in this region. As such, this study design does not account for the possibility of differences in soft tissue behavior in the maxilla versus the mandible. Second, anterior and posterior sites are not distinguished in this study, as this would have required a larger number of study participants and thus a dramatic increase in the length of the study. Third, for the same reason, sites with different gingival phenotypes are compared equally. Thus, the present study does not account for the possibility that different gingival phenotypes may behave differently.

Although the behavior of different gingival phenotypes will not be compared in the present study, this data will be gathered for analysis in the instance of significant difference in behavior of different phenotypes. Differences in behavior of thin and thick peri-implant gingival tissues have been observed in other cases. For example, patients with thin gingival tissues have been shown to have more peri-implant marginal bone loss in the first year after placement than those with thick tissues.[20-22] It is unknown whether tissue thickness plays a role in the rate or amount of peri-implant soft tissue collapse or

rebound. The data gathered in this study may be insufficient to make a determination, but its collection leaves open the possibility for its use in follow-on studies.

Finally, the present study does not account for the possibility of delayed soft tissue rebound nor does it measure the length of this theoretical delay. If the present study reveals absence of immediate soft tissue rebound, a follow-on study may address this question.

CHAPTER 5: Conclusions

This research, currently in the recruitment phase, will add to the body of literature providing understanding of soft tissue behavior during impression-making. The knowledge gained from this study will shed light on the validity of impression-making techniques for single implants in the esthetic zone.

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