Interproximal Papillae Adjacent to Single Implant Crowns in the Aesthetic Zone: Clinical and Radiographic Findings from a Multi-Private Practice Based Research Network (PBRN) and Post-Graduate Prosthodontics/Periodontology Residency Programs

by

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A thesis submitted in conformity with the requirements
For the degree of Master of Science
Graduate Department Dentistry
University of Toronto

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2010
Abstract
This study was designed to determine if the following two variables influence the predictability of the presence of the interproximal papilla between single implant supported crown adjacent to a natural tooth: a) the vertical measurement from the crest of bone on the natural tooth to the contact point, and b) the horizontal measurement from the platform of the implant to the adjacent tooth root. Retrospective data from a multi-private practice based research network (PBRN) and from a graduate teaching institution were analyzed specific to the maxillary anterior aesthetic zones. 116 patients who had 139 dental implants restored for at least 6 months, with mesial and/or distal sites (N= 253) were included in the analysis. Assessments of the implant position based on osseous crestal topography were conducted using standardized radiographs which were digitized and interpreted with "Access" software. The gingival papilla morphology was assessed using the Jemt Papillary Index from calibrated digital clinical photographs. Contrary to previously published data, our results indicate that the presence of interproximal papillae is independent of the vertical and horizontal measurements investigated.
Acknowledgements

First and foremost I would like to thank my family: my wife, Serene and my daughters, Nicole and Noelle for giving me continuous inspiration, support and motivation to meet and overcome all the challenges in the past 3 years. Your unconditional love, understanding, patience and immeasurable support gave me the strength and confidence in life to be who I am today.

I would also like to express my sincere gratitude to Dr. Asbjorn Jokstad for his supervision, time, patience and contributions to this project. His guidance, expertise and professionalism allowed this project to produce clinically relevant meaningful results.

To my advisory committee members, Dr. Howard Tenenbaum and Dr. Leslie Laing Gibbard, thank you both for your time, input and contributions to this project.

To other supporting team members; Ms. Janet DeWinter, Ms. Annie Tran, Dr. Mohammed Zahran, Dr. Joseph Fava, Mr. Albert Kim and all members of the Practice Based Research Network who participated to this project, thank you all for your contributions to this project. A special recognition is in order to Dr. Murray Arlin for his tremendous cooperation and contribution of data to this project. The quality and results of this project would not have been possible without all your help and support.

To my parents and sister, thank you all for your continuous love and encouragement throughout my entire life. Through my parents’ personal sacrifices and hard work, I am lucky and privileged to be given an opportunity to be in the dental profession.

Finally, I would like to express my humble gratitude to GOD for his guidance, immeasurable forgiveness, eternal love and protection for me and my family members.
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Introduction

The loss of the papilla around natural teeth is considered unacceptable by some patients due to phonetic problems caused by air or saliva escape during conversation, or lateral food impaction irritations (Tarnow et al. 1992). Even in the first clinical study that reported on implant-supported single crowns (Jemt et al. 1990) a concern was raised about the observed “gingival recession”. At the time it was believed that the incision or suturing techniques may have played a role in papilla preservation and studies were conducted on alternative flap-raising procedures to minimize this recession (Becker & Becker 1996). Reflecting on how the inter-dental papilla has received more attention over time, this has been demonstrated by the 3 papers reporting on a patient cohort treated with single implants in the Toronto Faculty of Dentistry Implant Prosthodontic Unit. In the first clinical study the issue of compromised peri-implant soft tissue was not addressed (Schmitt & Zarb 1993). The second study addressed the issue as a “soft tissue complication or nuisance findings” (Avivi-Arber & Zarb 1996). The third study reported that 27% of the implants showed some form of “soft tissue deficiency” (Laing Gibbard & Zarb 2002). Today, the presence and maintenance of the inter-dental/inter-implant papilla is considered as one of the most critical factors in the aesthetically challenging single tooth implant crown replacement therapy (Buser et al. 2006) particularly in the anterior sextants. This focus has been fuelled partially by the fascination for immediate post-extraction implant placement, although this approach has currently been criticized due to its highly unpredictable outcomes (Chen & Buser, 2009). Nevertheless, the presence or absence of the interdental papilla following the surgical placement of an implant in a
tooth space restored with a prosthetic crown is influenced by many factors, and the inter-dependency amongst these variables remains unclear (Priest 2007, Wheeler, 2007).

Over the last 2 decades investigators have attempted to elucidate the factors affecting papilla retention or regeneration using different clinical study methodology approaches, ranging from measuring the soft tissue height around implants (Table 1); assessing the mesial-distal distance between the implant and the neighbouring tooth and effects on the papilla (Table 2) and on the marginal bone loss (Table 3). Other innovative attempts to elucidate the topic have also been made (Table 4). Finally, numerous animal and laboratory studies have addressed the potential biological mechanisms that may be at play. The scope of the different study methodology approaches used implies the difficulties of understanding the complexity of biological factors that contributes to the role in the development of the tooth-implant interproximal papilla.
### Table 1: Studies investigating the soft tissue height around implants

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Study objective as reported</th>
<th>Study design</th>
<th>n-pas</th>
<th>Implant site</th>
<th>n-imp</th>
<th>Implant type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Lee DW, et al.</td>
<td>To compare the interproximal soft tissue dimensions adjacent to single implant restorations in the pre-molar position with those adjacent to the contra-lateral natural teeth</td>
<td>Retrospective case series</td>
<td>25</td>
<td>Single premolar/molar</td>
<td>25</td>
<td>AstraTech ST</td>
</tr>
<tr>
<td>2007</td>
<td>DeAngelo SJ, et al.</td>
<td>To characterize the clinical and microbiologic parameters of early soft tissue healing around one-stage dental implants, from placement to the first 3 months. The effect of soft tissue anatomy on such parameters also was investigated.</td>
<td>Prospective case series</td>
<td>21</td>
<td>Single mandible &amp; maxilla anterior &amp; posterior</td>
<td>21</td>
<td>AstraTech</td>
</tr>
<tr>
<td>2006</td>
<td>Lee DW, et al.</td>
<td>To compare the dimensions of interproximal soft tissue between adjacent implants in 2 different implant systems.</td>
<td>Retrospective case series</td>
<td>50</td>
<td>Partial dentate mandible &amp; maxilla posterior</td>
<td>170</td>
<td>Astra-TiO Brånemark -Mk2/3</td>
</tr>
<tr>
<td>2005</td>
<td>Glauser R, et al.</td>
<td>To histologically characterize the periimplant soft tissue barrier formed in humans around experimental one-piece mini-implants with different surface topography</td>
<td>Case study</td>
<td>5</td>
<td>Maxillary tuber</td>
<td>12</td>
<td>Experimental mini-implants</td>
</tr>
<tr>
<td>2005</td>
<td>Lee DW, et al.</td>
<td>To evaluate the effect of (1) the width of keratinized mucosa at the interproximal region, (2) the distance from the base of contact point to the crestal bone, and (3) the distance between two implants on the dimension of the interproximal papilla between two implants</td>
<td>Prospective case series</td>
<td>52</td>
<td>Partial dentate mandible &amp; maxilla posterior</td>
<td>144</td>
<td>Multiple systems</td>
</tr>
<tr>
<td>2003</td>
<td>Kan JY, et al.</td>
<td>To evaluate the dimensions of the peri-implant mucosa around 2-stage maxillary anterior single implants in humans after 1 year of function.</td>
<td>Prospective case series</td>
<td>45</td>
<td>Single maxilla anterior</td>
<td>45</td>
<td>Not reported</td>
</tr>
<tr>
<td>2003</td>
<td>Tarnow DP, et al.</td>
<td>To measure the average height of tissue from the crest of the bone to the tip of the papilla between two adjacent implants</td>
<td>Retrospective case series</td>
<td>33</td>
<td>Partial dentate mandible &amp; maxilla anterior &amp; posterior</td>
<td>272</td>
<td>Multiple</td>
</tr>
<tr>
<td>2000</td>
<td>Grunder U</td>
<td>To evaluate changes in papilla height and possible soft tissue shrinkage 1 year after final crown insertion in cases where tissue augmentation procedures around single-tooth implants in the maxillary central and lateral incisor area were performed</td>
<td>Prospective case series</td>
<td>10</td>
<td>Single maxilla central and lateral</td>
<td>10</td>
<td>Brånemark</td>
</tr>
</tbody>
</table>
Table 2: Studies on papilla and the proximal distance between implant and tooth

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Study objective as reported</th>
<th>Study design</th>
<th>n-pas</th>
<th>Implant site</th>
<th>n-imp</th>
<th>Implant type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Kourkouta S, et al.</td>
<td>To assess (i) interproximal tissue dimensions between adjacent implants in the anterior maxilla (ii) factors that may influence interimplant papilla dimensions and (iii) patient aesthetic satisfaction</td>
<td>Retrospective case series</td>
<td>15</td>
<td>Partial dentate</td>
<td>35</td>
<td>Not stated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maxilla anterior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Degidi M, et al.</td>
<td>To compare and evaluate bone and soft tissue levels in an immediately restored single implant positioned in the aesthetic anterior region</td>
<td>Retrospective case series</td>
<td>49</td>
<td>Single anterior</td>
<td>152</td>
<td>XiVe</td>
</tr>
<tr>
<td>2008</td>
<td>Lops D, et al.</td>
<td>A study on immediate implants placed into fresh extraction sites to evaluate the effect of the vertical and horizontal distances in determining the presence of the interproximal papilla</td>
<td>Prospective case series</td>
<td>46</td>
<td>Single mandible &amp; maxilla</td>
<td>46</td>
<td>Osseospeed</td>
</tr>
<tr>
<td>2008</td>
<td>Romeo E, et al.</td>
<td>To determine the correlation between the presence of papilla in single-tooth implant restorations and 1) vertical and horizontal distances and 2) gingival biotype</td>
<td>Prospective case series</td>
<td>48</td>
<td>Single anterior(24) premolar(24)</td>
<td>48</td>
<td>Straumann Std+</td>
</tr>
<tr>
<td>2007</td>
<td>Palmer RM, et al.</td>
<td>To evaluate patient satisfaction with single-tooth implant restorations and to compare this to clinicians’ ratings for the restorations, soft tissue profile and radiographic data</td>
<td>Retrospective case series</td>
<td>46</td>
<td>Single Maxilla anterior</td>
<td>46</td>
<td>Astra-ST</td>
</tr>
<tr>
<td>2005</td>
<td>Ryser MR, et al.</td>
<td>To determine if there is a difference in the papilla fill between implant and tooth comparing immediate provisionalized and delayed single tooth implant restorations</td>
<td>CCT Prospective study w/ concurrent controls</td>
<td>41</td>
<td>Single Maxilla anterior</td>
<td>41</td>
<td>Splines Steri-Oss</td>
</tr>
<tr>
<td>2004</td>
<td>Gastaldo JF, et al.</td>
<td>1) To evaluate the effect of the vertical and horizontal distances between adjacent implants (group 1) and between a tooth and an implant (group 2) on the presence of the interproximal dental papilla; and 2) to determine whether the interaction between the vertical and horizontal distances might be associated with the incidence of the papilla</td>
<td>Retrospective case series</td>
<td>48</td>
<td>Not reported</td>
<td>224</td>
<td>Not reported</td>
</tr>
<tr>
<td>2004</td>
<td>Henriksson K &amp; Jemt T</td>
<td>To measure changes in buccal tissue volume after placing restorations with single-implant crowns using two different abutment systems and to measure changes in soft tissue volume adjacent to the implant restorations during the first year of function</td>
<td>CCT Prospective study w/ concurrent controls</td>
<td>18</td>
<td>Single Maxilla Centrals</td>
<td>18</td>
<td>Brånemark-mk3</td>
</tr>
<tr>
<td>2001</td>
<td>Cooper LF, et al.</td>
<td>To evaluate the clinical survival rate after rapid loading of unsplinted endosseous root-form implants replacing the loss of 1 or 2 teeth in the anterior maxilla</td>
<td>Prospective case series</td>
<td>47</td>
<td>Single Maxilla anterior</td>
<td>53</td>
<td>Astra-ST</td>
</tr>
</tbody>
</table>
Table 3: Studies on the bone loss of the proximal (mesial-distal) distance between the implant and tooth

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Study objective as reported</th>
<th>Study design</th>
<th>n-pas</th>
<th>Implant site</th>
<th>n-imp</th>
<th>Implant type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Chang M &amp; Wennström JL.</td>
<td>To evaluate longitudinal changes in bone topography and tooth/implant relationship in patients with single implants with a micro threaded, conical marginal part (Astra Tech ST implants)</td>
<td>Retrospective case series</td>
<td>31</td>
<td>Single maxilla anterior</td>
<td>31</td>
<td>Astra-ST-TiO</td>
</tr>
<tr>
<td>2009</td>
<td>Kwon HJ, et al.</td>
<td>To investigate whether the tooth-side bone level remains the dominant factor affecting the interproximal papilla dimension around a single implant with a micro thread, conical seal, and platform-switched design</td>
<td>Retrospective case series</td>
<td>17</td>
<td>Single mandible &amp; maxilla anterior &amp; posterior</td>
<td>17</td>
<td>AstraTech ST</td>
</tr>
<tr>
<td>2008</td>
<td>Reddy MS, et al.</td>
<td>To determine changes in interdental papillae, alveolar bone loss, aesthetics, and initial healing survival when 1-piece narrow-diameter implants were immediately loaded in sites with limited tooth-to-tooth spacing</td>
<td>Prospective case series</td>
<td>17</td>
<td>Single mandible/maxilla anterior</td>
<td>31</td>
<td>Biohorizons</td>
</tr>
<tr>
<td>2003</td>
<td>Cardarocolli G, et al.</td>
<td>To evaluate longitudinal alterations in radiographic bone topography at proximal sites of three-unit implant-supported fixed partial prostheses during the first 3 years after bridge installation, in relation to vertical and horizontal inter-unit distances</td>
<td>Retrospective case series</td>
<td>28</td>
<td>Single Maxilla anterior</td>
<td>140</td>
<td>Brånemark</td>
</tr>
<tr>
<td>2003</td>
<td>Krennmaier G, et al.</td>
<td>To investigate the crown as well as the periodontal status, including the proximal bone resorption, during the follow-up period of teeth adjacent to single-tooth implants, especially comparing their behaviour in the anterior and posterior regions</td>
<td>Retrospective case series</td>
<td>64</td>
<td>Single mandible &amp; maxilla anterior vs posterior</td>
<td>78</td>
<td>Frialit-2</td>
</tr>
<tr>
<td>2001</td>
<td>Choquet V, et al.</td>
<td>To characterize the bone level and papilla height in relation to the contact point adjacent to single-tooth, implant-supported restorations</td>
<td>Retrospective case series</td>
<td>26</td>
<td>Single Maxilla anterior</td>
<td>27</td>
<td>Brånemark</td>
</tr>
<tr>
<td>2001</td>
<td>Thilander B, et al.</td>
<td>To evaluate the long-term effect on occlusion and marginal conditions of osseointegrated titanium implants, installed in adolescents to replace missing teeth in different areas</td>
<td>Prospective case series</td>
<td>18</td>
<td>Single anterior</td>
<td>47</td>
<td>Brånemark</td>
</tr>
<tr>
<td>1998</td>
<td>Andersson B, et al.</td>
<td>To present the results after 5 years of loading of 65 CeraOne (Nobel Biocare) crowns</td>
<td>Prospective case series</td>
<td>57</td>
<td>Single maxilla</td>
<td>65</td>
<td>Brånemark</td>
</tr>
<tr>
<td>1996</td>
<td>Henry PJ, et al.</td>
<td>To present final treatment outcome and clinical effectiveness following 5-years of functional loading of osseointegrated implants for single-tooth replacement</td>
<td>Prospective case series</td>
<td>92</td>
<td>Single mandible &amp; maxilla</td>
<td>107</td>
<td>Brånemark</td>
</tr>
<tr>
<td>1993</td>
<td>Esposito M, et al.</td>
<td>To study marginal bone loss at single implants and adjacent tooth surfaces and to determine the influence of different factors on the marginal bone level changes</td>
<td>Prospective case series</td>
<td>58</td>
<td>Single mandible &amp; maxilla anterior &amp; posterior</td>
<td>71</td>
<td>Brånemark</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Study objective as reported</td>
<td>Study design</td>
<td>n-pas</td>
<td>Implant site</td>
<td>n-imp</td>
<td>Implant type</td>
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</tr>
<tr>
<td>2008</td>
<td>Lai HC, et al.</td>
<td>To evaluate the alterations of soft tissue around a single-tooth implant in the anterior maxilla with a new defined pink aesthetic score at the time of crown placement and 6 months post-loading</td>
<td>Prospective case series</td>
<td>29</td>
<td>Single maxilla anterior</td>
<td>29</td>
<td>ITI</td>
</tr>
<tr>
<td>2005 Schropp L, et al.</td>
<td>To compare the peri-implant and prosthetic conditions for single-tooth implants placed according to the delayed-immediate and the delayed protocols</td>
<td>RCT Randomized controlled trial;</td>
<td>46</td>
<td>Single mandible &amp; maxilla anterio+premolar</td>
<td>46</td>
<td>Osseotite</td>
<td></td>
</tr>
<tr>
<td>2004 Misch CE, et al.</td>
<td>To propose a technique, the split-finger approach, to preserve/promote papillae formation</td>
<td>Prospective case series</td>
<td>21</td>
<td>Single Maxilla anterior</td>
<td>39</td>
<td>Maestro</td>
<td></td>
</tr>
<tr>
<td>2003 Kan JY &amp; Rungcharassaeng K</td>
<td>To study an interimplant papilla preservation technique involving alternate immediate implant placement and provisionalization</td>
<td>Prospective case series</td>
<td>6</td>
<td>Partial dentate Maxilla</td>
<td>14</td>
<td>Replace-HA</td>
<td></td>
</tr>
<tr>
<td>2003 Priest G</td>
<td>To answer questions re: gingival responses to single-tooth implants</td>
<td>Retrospective case series</td>
<td>51</td>
<td>Single mandible &amp; maxilla</td>
<td>55</td>
<td>3i</td>
<td></td>
</tr>
<tr>
<td>2001 Aparicio C, et al.</td>
<td>To study a combination of tilted and axial implants used in patients with severely resorbed posterior maxillae as an alternative to sinus grafting</td>
<td>Retrospective case series</td>
<td>25</td>
<td>Partial edentate</td>
<td>101</td>
<td>Brånemark</td>
<td></td>
</tr>
<tr>
<td>2001 Grossberg DE</td>
<td>To describe a fixed and reproducible reference line which can be used to measure changes in the height of the interimplant papillae.</td>
<td>Case study</td>
<td>12</td>
<td>Single Maxilla anterior</td>
<td>12</td>
<td>Brånemark</td>
<td></td>
</tr>
<tr>
<td>1999 Chang M, et al.</td>
<td>To assess and compare patients' and clinicians' judgments of the aesthetic outcome of implant-supported single-tooth replacements</td>
<td>Prospective case series</td>
<td>29</td>
<td>Single Maxilla anterior</td>
<td>41</td>
<td>Brånemark</td>
<td></td>
</tr>
<tr>
<td>1999 Chang M, et al.</td>
<td>To make a comparative evaluation of crown and soft tissue dimensions between implant-supported single-tooth replacements and the contralateral tooth</td>
<td>CCT Prospective study w/ concurrent controls</td>
<td>20</td>
<td>Single Maxilla anterior</td>
<td>20</td>
<td>Brånemark-std</td>
<td></td>
</tr>
<tr>
<td>1999 Jemt T</td>
<td>To propose a clinical technique to create gingival papillae by means of guiding the tissue during the postsurgical swelling period and to evaluate the results in a study of retrospective consecutive patients by means of the previously presented papilla index</td>
<td>Retrospective case series</td>
<td>55</td>
<td>Single Maxilla anterior</td>
<td>63</td>
<td>Brånemark</td>
<td></td>
</tr>
<tr>
<td>1995 Andersson B, et al.</td>
<td>To present results and experiences from a continuing prospective study on single-tooth restorations using the CeraOne concept</td>
<td>Prospective case series</td>
<td>91</td>
<td>Single maxilla anterior</td>
<td>130</td>
<td>Brånemark</td>
<td></td>
</tr>
</tbody>
</table>
The conclusions from the reviewed studies are quite conflicting and indicate a range of dimensions that exists relative to adjacent structures, whether tooth or implant. Examples include: “…the vertical distance on the tooth side from the crest of bone to the height of the papilla between a tooth and an implant distance was an average of 4.225 mm with a range of 3.0-5.0 mm” (Grunder 2000); and “…when the measurement from the contact point to the crest of bone was 5mm or less, the papilla was present almost 100% of the time. When the distance was ≥6mm, the papilla was present 50% of the time or less…” (Choquet et al. 2001); and “…as for the horizontal distance from the implant to the adjacent tooth, bone loss at tooth surface was most severe for a horizontal distance of less than 2.0mm” (Esposito et al. 1993).

Probable explanations for the conflicting findings are combinations of inferior study designs, inadequate study power, non-standardized operational measurements, and post-hoc measurements instead of planned trials. Additional factors include publication bias and variations in factors related to operator, patient, procedure, implant type and setting. These are just some of the suspected confounding factors that may influence the final clinical outcomes reported in the literature (Teughels et al. 2006).

In spite of these apparent complexities, numerous clinicians have proposed patient management approaches using clinical guidelines and parameters, with claims of predictability in preserving or creating the interdental papillae. (Kois 2001, Tarnow et al. 2003, Priest 2007, Wheeler, 2007). The clinical guidelines cited in these studies are being taught and echoed from various educational institutions, podium speakers, and implant conferences around the world.

A critical appraisal of the study methodology used as a basis for these claims reveal the studies had relatively small sample sizes, potential selection bias, examination of a narrow range of implant types, employed a variety of clinical protocols and reported results with short term follow up times. The research design flaws leads one to question if one can apply the proposed simple formulae to clinical situations. Moreover, as it is apparent that the mucogingival-bone response to implants varies with their design, the guidelines can at best be applicable only to the implant types used in the situations described in the previous studies. In addition, these studies provide a wide range of results with large standard deviations. Hence,
further detailed investigations are required to predict and explain the various factors that influenced the results obtained from the studies cited.

Finally, clinicians' empirical, long-term, follow-up observational experiences also suggest that by following these clinical guidelines for relative positioning of implant to bone crest and adjacent teeth may not consistently generate a predictable outcome clinically. Various clinical outcomes have been observed after a single aesthetic implant crown has been inserted. According to our own clinical experience, the following have been observed:

1. The inter-dental-implant papilla may be absent initially but will fill in over a period of time after the implant crown is restored, 2. The inter-dental-implant papilla may be present initially but will recede eventually and 3. The inter-dental-implant papilla may be absent initially and remain absent over a period of time. These findings are in agreement with those previously reported in the literature. (Schropp et al. 2008, Teughles et al. 2009).

If one acknowledges the multifactor interplay of this complex topic, it stands to reason that relative implant position and the distance between the crest of bone and contact point, which are only a 2-dimensional measurements, cannot be regarded as sole determinants of 3-dimensional, aesthetically optimal, inter-dental-implant papilla fill. It remains to be determined what other clinical variables may influence this outcome. In addition, further investigations are warranted to determine the intricate interplay of factors that contribute to the ranges of results obtained from the previous studies.

The purpose of the present study was to conduct a retrospective, cross-sectional study within a Practice Based Research Network (PBRN) of private practitioners consisting of general dentists and specialists to assess the presence or absence of interproximal papillae adjacent to single implant crowns in the aesthetic zone. In addition, data were gathered from the post-graduate Prosthodontic clinic (Implant Prosthodontic Unit, IPU) and the post-graduate Periodontology clinic (Oral Reconstruction Center, ORC) from the University of Toronto. The aim was to review the clinical, photographic and radiographic outcomes as they relate to the final aesthetic results for the single tooth implant restoration and determine whether: 

a) the vertical measurement from the base of the contact area to the crest of the bone on the natural tooth and b) the horizontal measurement from the tooth to the implant
is reliable predictor for the presence or absence of the interproximal papilla adjacent to single-tooth implants.

**Hypothesis**

The following null hypotheses were set: A) The vertical measurement from the crest of the bone adjacent to the natural dentition to contact point is **not a reliable predictor** for the presence of the inter-dental-implant papilla; B) The horizontal measurement from the platform of the implant to the adjacent tooth is **not a reliable predictor** for the presence of the inter-dental-implant papilla.
Material and Methods

A cross-sectional study design was used where data were gathered from a Toronto-based Dental PBRN and from the Implant Prosthodontic Unit (IPU) and Oral Reconstruction Center (ORC) located at the Faculty of Dentistry, University of Toronto. The PBRN initially consisted of 23 private dental offices (11 specialists and 12 general practitioners) in the Toronto area (Appendix I). An invitation letter (Appendix II) to participate in this study with details of the requirements for this study was issued to the members of the PBRN. The study was approved by the U of T Health Sciences Research Ethics Board (REB), protocol #23187. Informed consent (Appendix III) was obtained from all patients participating in the research.

A website (www.dentalpbrn.ca) was set up hosting a data management program (PHP Scriptz) to enable online completion of forms and uploading of media files. Each member of the PBRN was provided with a password to a portion of the website where each member could collate and store patient-non-identifiable data as well as digitized radiographs and clinical photographs. Each member had restricted security access and only had access to their own part of the website for the data entry process.

Figure 1: www.dentalpbrn.ca web shot (Accessed February 2010)
To avoid bias of patient case selections, i.e., “best case” selection, the individual PBRN member did not have access to compare to other clinicians’ submitted cases during the data entry and gathering process. To further avoid sample selection bias by the dentists who performed the procedures within their own patient base, the recall of the treated patients took place as follows:

From each dental practice, a list of all patients that qualified to meet the inclusion and exclusion criteria (Table 5) for this study was made available to the principle investigator (M.L.) of this project.

A computer-generated randomized process was used to select a list of 20 patients from the entire list. Since each office was only required to submit 10 patient cases, the first 10 patients according to availability who attended the respective offices were submitted for the required clinical data.

Table 5: Patient Inclusion and Exclusion Criteria

<table>
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<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
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<tbody>
<tr>
<td>-Patients with single implant tooth replacement in the aesthetic zone between the maxillary canines (13-23) area with natural dentition on both adjacent mesial and distal sites.</td>
<td>-Patients who had soft tissue grafting prior to or in conjunction with implant surgery.</td>
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<tr>
<td>-The final implant-supported crown restoration must have been in function for a period of at least 6 months. (Choquet et al. 2001)</td>
<td>-Patients who had adjunctive surgical procedures after insertion of final crown restoration. (I.e. further connective tissue or soft tissue grafting, hard tissue grafting, treatment of peri-implantitis, etc…)</td>
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<tr>
<td></td>
<td>-Patients who were taking any medications known to affect or alter periodontal soft tissue dimensions.</td>
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<tr>
<td></td>
<td>-Patients who had “ridge lap” type of prosthesis or pseudo-papilla regeneration made of pink acrylic or porcelain to artificially create the interproximal papillae.</td>
</tr>
</tbody>
</table>
Since the principle investigator (M.L.) was not part of any of the dental practices and not privileged to any clinical or chart information other than the patient names, the computer generated selection process of the patient names ensured randomization selection of clinical sample data collected without any chance of selection bias by the treating dentist. For the principle investigator’s practice, the selection of the patient base was chosen by an independent participant (office manager) who was blinded to the purpose of the study.

Participants were encouraged to enter all cases, regardless of final quality. Once all data were collected, the website was opened to all professional participants to view other cases but privacy and anonymity were still assured. Only identification of the cases by serial numbers was recorded.

10 cases per private practice dental office, 25 cases from the IPU and 25 cases from the ORC, yielding a total of 100 single implant restored cases was considered to be the minimum sample size. Given that each implant had a natural adjacent tooth on either side, it was recognized that both mesial and distal interproximal papilla could be assessed thus yielding 200 sites as the final sample size for interpretation.

The appraisal and evaluation of the clinical, photographic and radiographic records were done by two post graduate Prosthodontic residents who were calibrated and blinded examiners (J.F., M. Z.) and had access to all the PBRN members’ local sites.

Participants and Recruitment

Dentists: both general practitioners and specialists in the Toronto area who provided implant dental care were invited to join the practice based research network (PBRN) (Appendix I and II). The members of the PBRN were advised that they should invite and recall patients selected by the randomization process who were treated with single tooth implant restorations in the aesthetic zone (#13-23) adjacent to natural dentition. Moreover, clinicians were advised that the primary investigator (M.L.) and an auxiliary staff member would be present at their clinic with the PBRN member or their designee randomly selected amongst their recall patients whether or not they met all inclusion criteria (Table 5) prior to invitation and collection of data.
**Patients:** patients treated previously with single implants who returned to their clinicians' offices for their regular recall appointments for evaluation were invited to participate in the study (Appendix III). They were advised in a letter that their dentist was part of a PBRN and that their anonymity would be protected.

**Data Collection**
To ensure maximal consistency in data collection from various participating clinics, the protocol in the form of written instructions for clinical data collection was provided to all participating offices (Appendix IV).

A training session demonstrating the data collection process was conducted with all members of the PBRN to ensure consistent standardization of the data collection process.

**Clinical analyses**
Clinical photographs were measured and interpreted by 2 trained post-graduate Prosthodontic residents who were calibrated blinded examiners (Drs. J.F and M.Z.). Inter- and intra-examiner reliability kappa values were assessed to determine accuracy of their measurements. The interdental papilla volume was recorded based on the index proposed by Jemt (Jemt 1997) (Table 6).
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<thead>
<tr>
<th>Score</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>No papilla is present, and there is no indication of a curvature of the soft tissue contour adjacent to the single-implant restoration</td>
</tr>
<tr>
<td>1</td>
<td>Less than half of the height of the papilla is present. A convex curvature of the soft tissue contour adjacent to the single-implant crown and the adjacent tooth is observed.</td>
</tr>
<tr>
<td>2</td>
<td>At least half of the height of the papilla is present, but not all the way up to the contact point between the teeth. Papilla is not completely in harmony with the adjacent papilla between the permanent teeth. Acceptable soft tissue contour is in harmony with adjacent teeth.</td>
</tr>
<tr>
<td>3</td>
<td>The papilla fills up the entire proximal space and is in good harmony with the adjacent papilla. There is optimal soft tissue contour.</td>
</tr>
<tr>
<td>4</td>
<td>The papilla is hyperplastic and covers too much of the single-implant restoration and/or the adjacent tooth. The soft tissue contour is more or less irregular.</td>
</tr>
</tbody>
</table>
Radiographic analyses

All radiographs were taken using parallel long cone radiographic technique and a film holder (Rinn holder, DENTSPLY) for anterior periapical radiograph size #2.

Different sized gutta percha cones were used to fit interproximally at the level of the tip of the interdental papilla to the tip of the papilla soft tissues radiographically.

The radiographs were digitized using a digital scanner or digital camera. The images were treated using “Access” software to record and document the measurements. No modifications were made to the pictures. Measurements were performed by operators trained to read implant radiographs. The Jemt “0” value was set at the implant abutment junction (IAJ). Measurements were expressed as pixels and then converted to millimetres and calibrated to the actual known value for the shoulder diameter of the implant.
Figure 2: Vertical and horizontal measurements on radiographs

W: The horizontal measurement of the width of the implant shoulder at the implant abutment junction (IAJ) served as a calibration tool and a parallel reference line to relate the other vertical measures.

1) The vertical distance between the shoulder of the implant and the most coronal point of the bone level contacting the implant.

2) The vertical distance between the shoulder of the implant and the most coronal point of the bone level contacting the tooth.

3) The vertical distance between the shoulder of the implant and the most coronal papilla level.

4) The vertical distance between the shoulder of the implant and the most apical level of the contact point between the crown and the teeth and the implant.

5) The vertical distance between the crest of bone on the natural tooth and the contact point.

6) The horizontal mesio-distal distance between the tooth and the implant at the implant shoulder.
Calibration:
A reference line had to be set to determine the remaining measurements. Because it is a known diameter, the implant abutment joint was selected. A correction factor was therefore calculated between the radiographic measurement and the known value. All radiographs were corrected using this principle to calibrate the readings between the series of radiographs (Choquet et al. 2001).

Two calibrated examiners blinded to the purpose of the study provided the radiographic measurements and Jemt index scores. Both the intra-observer variability and inter-observer variability showed mean differences to be negligible and clinically irrelevant, i.e., within 0.2 mm the measurement variability was 96%. The Jemt Papillary Index scores were in agreement 100% of the time and very high precision on the radiographic measurements was achieved (Table 7).

Table 7: Inter- and intra-examiner reliability of assessor scoring: 1 and 2 for radiographic measurements (1-6) and clinical assessment of the Jemt Papilla Index. (m= mesial, d= distal).
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Statistics
Descriptive statistics were used to present the data in terms of means and standard deviations.
**Results**

Clinical pictures and radiographs of 139 patients were uploaded to the PBRN website. 21 patients were excluded since only the papillae and bone levels were measured in interproximal sites between the dental implant and natural tooth and not between crown or pontic and the implant or between 2 implants. (Table 8) In addition, 46 out of 299 (15%) interdental papilla sites were excluded in the analyzed data due to incomplete dental charting.

**Table 8: Patients included in the study**

<table>
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<tr>
<th>Implant situation</th>
<th>IPU/ ORC patients</th>
<th>PBRN patients</th>
<th>Prox. Site 1</th>
<th>Prox. Site 2</th>
<th>Total number of Sites</th>
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<td>Tooth-Imp.-Tooth</td>
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<td>69</td>
<td>58</td>
<td>58</td>
<td>116</td>
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<tr>
<td>Imp.-Imp.-Tooth</td>
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<td>6</td>
<td>0</td>
<td>14</td>
<td>14</td>
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<tr>
<td>Crown/Pontic-Imp.-Tooth</td>
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<td>3</td>
<td>0</td>
<td>7</td>
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<tr>
<td>Total</td>
<td>38</td>
<td>78</td>
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**Table 9: Summary of gathered data**

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<tr>
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<th>PBRN</th>
<th>Data Gathered</th>
<th>Total Data Analyzed</th>
</tr>
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<td>Patients</td>
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<td>116</td>
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<td>Implants</td>
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<td>Sites</td>
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<td>186</td>
<td>278</td>
<td><strong>253</strong></td>
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Thus, data from 116 out of 139 (83%) patients were recorded with a total of 253 tooth-implant papilla sites. The average age of the patients was 53 years and there was about equal distribution between genders. The majority of patient cases were collected from the PBRN network (Table 8 and 9).

The most common intra-oral locations for implant placement were central incisors (45%), followed by lateral incisors (40%) and cuspids (25%).
The observed crowns were on average 3.5 years old, with a range from 1-18 years. The majority of crowns had been placed during the last 4-7 years (Fig. 3).

The majority of implants were either Nobel Biocare or Steri-Oss (Fig. 4). This bias may partly be explained since by the collected data from the Implant Prosthodontic Unit (IPU), which exclusively used implants from Nobel Biocare. In addition, many of the participating members of the PBRN also used the Nobel Biocare implant system.
Jemt Scores
The complete range of Jemt Papilla Index scores was noted. The most predominant score was 2. (i.e. at least half the height but not up to the contact point). The other scores showed a normal distribution around a score of 2 on both the distal and mesial sides (Fig. 5)

Figure 5: Distribution of observed Jemt Papillary Index (left: mesial, right: distal side)

Radiographic measurements

Figure 6: Implant shoulder to the bottom of the gingival pocket depth measurements (left: mesial, right: distal side)
The depths between the implant shoulder to the bottom of the gingival pockets; i.e. the “1” marked on the figure below had an average of 1.4mm (SD 0.8) mesially and 1.5 mm (SD 0.8) distally. The measurements ranged between -0.5 (supracrestal) and 5 mm.
Figure 7: Implant shoulder to the bone level on adjacent tooth measurements (left: mesial, right: distal side)

The vertical distance between the implant shoulder to the most coronal point of the bone level contacting the adjacent tooth; i.e. the “2” marked on the figure, had an average of 1.3 mm (SD 1.2) mesially and 0.5 mm (SD 1.2) distally. The measurements ranged between -2 (located more coronally) and 4.6 mm.

Figure 8: Implant shoulder to the top of the papilla measurements (left: mesial, right: distal side)

The vertical distance between the implant shoulder to the most coronal papilla level i.e. the “3” marked on the figure was as an average of 4.7 mm (SD 1.7) mesially and 3.7 mm (SD 1.6) distally. The measurements ranged between 2 mm and 11 mm.
Figure 9: Implant shoulder to the contact point distance measurements (left: mesial, right: distal side)
The vertical distance between the implant shoulder to the most apical level of the contact point between the crown and the adjacent teeth, i.e., the “4” marked on the figure had an average of 6.9 mm (SD 1.8) mesially and 5.3 mm (SD 1.9) distally. The measurements ranged between 2 mm and 12 mm.

Figure 10: Crestal bone to contact point distance measurements (left: mesial, right: distal side)
The vertical distance between the crest of bone on the natural tooth and the contact point, i.e. the “5” on the figure had an average of 5.5 mm (SD 1.5) mesially and 4.9 mm (SD 1.5) distally. The measurements ranged between 2 mm and 11 mm.
Figure 11: Horizontal distance between implant and adjacent tooth at the shoulder level (left: mesial, right: distal side)
The horizontal mesio-distal distance between the implant and the adjacent tooth at the implant shoulder, i.e., the “6” on the figure had an average of 2.5 mm (SD 1.2) mesially and 1.6 mm (SD 0.9) distally. The measurements ranged between 0 (contact with adjacent tooth) and 7.6 mm.

Figure 12: Relationship between Jemt Papillary Index and Distance from bone crest to papilla height (Left: Mesial, Right: Distal side)
The distributions of the Jemt index relative to the height of the papillae (in mm) are shown in figure 12. A clear relationship between papilla height and higher Jemt scores can be seen for the mesial side, but the distal is more uncertain. It may be due to the inclusion of cuspids which have different anatomical features on the distal as compared to the incisor teeth. The average thickness of the papilla on both sides were 3.4 mm (SD 1.2)

Figure 13: Relationship between Jemt Papillary Index and Distance from bone crest to contact point. (Left: Mesial sites, Right: Distal sites)

When the Jemt index is scored according to the actual distance between the crestal bone and the contact point (i.e. “5” in the previous figures) it is apparent that the papillae can demonstrate a wide range of thicknesses within the scoring categories. e.g., Score 3, a complete fill of the interproximal triangle was apparent for papillae ranging between 2.3 to 8.5 mm.
Figure 14: Jemt Papillary index according to the 6 radiographic measurements – Distal sites:

1) The vertical distance between the shoulder of the implant and the most coronal point of the bone level contacting the implant.

2) The vertical distance between the shoulder of the implant and the most coronal point of the bone level contacting the tooth.

3) The vertical distance between the shoulder of the implant and the most coronal papilla level.

4) The vertical distance between the shoulder of the implant and the most apical level of the contact point between the crown and the teeth and the implant.

5) The vertical distance between the crest of bone on the natural tooth and the contact point.

6) The horizontal mesio-distal distance between the tooth and the implant at the implant shoulder.
Figure 15: Jemt Papillary Index according to the 6 radiographic measurements – mesial sites:

1) The vertical distance between the shoulder of the implant and the most coronal point of the bone level contacting the implant.
2) The vertical distance between the shoulder of the implant and the most coronal point of the bone level contacting the tooth.
3) The vertical distance between the shoulder of the implant and the most coronal papilla level.
4) The vertical distance between the shoulder of the implant and the most apical level of the contact point between the crown and the teeth and the implant.
5) The vertical distance between the crest of bone on the natural tooth and the contact point.
6) The horizontal mesio-distal distance between the tooth and the implant at the implant shoulder.
Figures 14 and 15 show the box plots for all 6 variables measured for the respective distal and mesial sites against the Jemt index. A clear pattern between the 6 different radiographic measurements and the papilla scores is not demonstrable.

**Figure 16: Relationship between the Jemt Papillary index and Horizontal distance between implant and adjacent tooth: Distal sites left, Mesial sites right,**

The respective distal and mesial site for the Jemt index relative to the horizontal measurement from the platform of the implant to adjacent root does not indicate any clear relationship.

Figure 13 shows the vertical distance between the crest of bone on the natural tooth and the contact point to Jemt index score. It seems that the mean measurements of approximately 5.0 mm are consistent for both sites and all Jemt scores with a linear plot. In other words, the 5.0 mm rule of crest of bone on the tooth side to contact point can present results of absolutely no papilla fill to full papilla fill. These results imply that there is no relationship between the crest of bone on the natural tooth to contact point as a predictor for the degree of presence or absence of interproximal papillae. Likewise figure 16 indicates that the horizontal dimension displays a linear relationship indicating that there is no relationship between the distance between the implant and natural tooth to the presence or absence of an interproximal papilla.
Our results indicate that we should accept our null hypotheses that:

A) The vertical measurement from the crest of the bone adjacent to the natural dentition to contact point is not a reliable predictor for the presence of the interdental-implant papilla; B) The horizontal measurement from the platform of the implant to the adjacent tooth is not a reliable predictor for the presence of the interdental-implant papilla
Discussion

The goal of implant dentistry is to restore and rehabilitate the patient’s dentition to physiologic contour, function, comfort and further to facilitate speech, health, aesthetics and in so doing mimic the natural dentition. Many authors have addressed the importance of comprehensive examination, diagnosis and judicious multi-disciplinary treatment planning to achieve optimal clinical predictable results in the maxillary aesthetic zones with dental implant replacement therapy.

Most academics and clinicians would agree that dental practice in the “real world” is different at many levels than practice in the institutional setting. As such, a “Private Practice-Based Research Network” (PPBRN) could contribute valuable, realistic and practical information to the dental community. Hence there are numerous benefits and advantages to obtaining research data and results from the Private Practice-Based Research Network. However, there are also numerous obstacles and barriers to initiating, operating and maintaining such a PPBRN. Constant on-going maintenance was required to confirm accuracy of data collection and data entry along with cooperation from all members of the PPBRN. Despite their advantages, practice-based studies do not have the same scientific rigour as controlled studies and may lack standardization. However, this can be compensated for by using a large number of clinicians to provide large sample sizes that would otherwise not be feasible in an institution-based controlled study. In addition, the study design and methodology of the study can be originated, implemented, monitored and maintained by principal investigators familiar with scientifically sound study protocol designs.

It is also notable that the majority of all research in all disciplines of dentistry, including prosthodontics and dental implant research has been performed in academic institutions and/or dental hospitals. Yet the critical appraisal process of any scientific research literature is to determine the level of “external validity” of the results and conclusions drawn from highly controlled clinical research studies. Even when the study design makes all attempts to ensure internal and external validity, those reading the various publications are expected to have a “leap of faith” to therefore expect the results of the various studies to translate directly to everyday
private clinical practice. Although the research carried out is scientifically sound, this does not necessarily imply a direct link to the problems encountered in the private dental practice setting.

With regards to the maintenance or reestablishment of the inter-dental papilla, the **biologic or anatomical parameters** such as patients’ relative tooth position, morphtype of the periodontium, biotype of the periodontium, tooth shape, position of the osseous crest (Esposito et al. 1993), crestal alveolar bone height, inter-proximal bone height adjacent to the natural tooth, dimension of inter-proximal spaces both horizontally and vertically, and the morphological features of the adjacent natural tooth may influence the inter-dental-implant papilla (Tarnow et al. 1992, Esposito et al. 1993). It has also been suggested that the height of the interdental papilla is determined by 1) the level of the interproximal bone in 3 dimensions, 2) the biologic width and 3) the size and shape of the gingival embrasures (Choquet et al. 2001). As well, it is thought that variations and ranges of averages exist within these 3 factors which might create significantly altered heights of interproximal papilla between a tooth and an adjacent dental implant.

**Technical parameters** such as implant design, type and surface, design of the abutment or prosthetic component or altered designed abutments such as “platform switching”, provisionalization contours, size and contour of the final restoration, ceramic abutments, ceramic crowns, shading with characterizations and location of the contact area have all been suggested to influence the preservation or regeneration of the inter-dental-implant papilla (Choquet et al. 2001, Tarnow et al. 2000, 2003).

**Clinical parameters** of treatment planning decisions such as extrusion via orthodontic interventions prior to root extraction, extraction and immediate surgical implant placement, extraction with socket preservation and staged approach, soft tissue grafting prior to or in conjunction with implant placement, osseous grafting in the horizontal and vertical component, immediate provisionalization to support adjacent papillae, papilla sparing incision flap techniques, creative second stage surgical
protocols, and alterations to the contralateral natural tooth to artificially apically adjust the location of the contact area have all been reported to optimize papilla preservation or to minimize the deficient interproximal gingival papillae by means of regeneration or artificial creation of the inter-dental-implant papillae.

Choquet et al. (2001) reported the clinical and radiographic evaluation of the papilla level adjacent to the single-tooth dental implant in the vertical component only. The authors suggested future studies should also take into account the horizontal distance between tooth and implant. The results of the present study revealed the occurrence of some papillae with 9.0 mm or more between the bone crest and the contact point. When the Jemt Papilla Index is scored according to the actual distance between the crestal bone and the contact point (figure 13) it is apparent that the papillae can demonstrate a wide range of thicknesses within the scoring categories. e.g., Score 3, a complete fill of the interproximal triangle was apparent for papillae ranging between 2.3 to 8.5 mm. Figure 13 shows the vertical distance between the crest of bone on the natural tooth and the contact point as it relates to the Jemt Papilla Index score. It seems that the mean measurements of approximately 5.0 mm are consistent for both sites and all Jemt scores with a linear plot. In other words, the 5.0 mm rule of crest of bone on the tooth side to contact point can present results of absolutely no papilla fill to full papilla fill. This result would imply that there is no relationship between the crest of bone on the natural tooth to contact point as a predictor for the degree of presence or absence of interproximal papillae.

As well the horizontal component of the biologic width around implants was reported to be a factor contributing to preservation or obliteration of the vital peak of alveolar bone providing blood supply to the corresponding soft tissue or the papilla (Tarnow et al. 2000). Likewise the results of this study indicate that the horizontal dimension displays a linear relationship indicating that there is no relationship between the distance between the implant and natural tooth to the presence or absence of an interproximal papilla (figure 16).

The combination and interrelationships between multiple variables such as anatomical features of adjacent natural tooth as well as various technical and clinical parameters all contribute to the various reported clinical results. This fact may be
responsible for the confusing and controversial results reported in the current literature regarding papilla maintenance or regeneration. Further studies with scientifically valid research methodology, larger sample size and long term follow-up periods are required to understand this complex topic fully.

It should be noted that this retrospective study reported has contained many variables: type, design, surface of implants, various implant placement locations, vertical location of implant crest and horizontal distance from adjacent natural tooth, etc… that may affect the average vertical height of the interproximal papillae between implant and tooth.

There are some potential limitations to this study as follows: In order to reduce any edema and inflammation that might lead to inaccurate measurements and to avoid any interpretation of pseudo-pocketing due to inflammation, patients should ideally have had a professional prophylactic cleaning and thorough scaling and root planning 2-8 weeks prior to clinical measurements being recorded (Tarnow et al. 1992). The feasibility and practical aspect of initiating this prophylactic protocol could decrease patient participation and sample size due to the required extra time and effort required by the patients and members of the PBRN. Therefore this protocol was omitted which may introduce inaccuracy and overestimation of the size of the interproximal papillae of the data gathered. For example, some interdental papilla sites might have been edematous leading to increased soft tissue fill of the embrasure areas. The members of the PBRN were invited to participate in this study and those that volunteered would usually represent experienced clinicians willing to share and show-case their final treatment results. This again may not be a true representation of what is reflective of "real life" dentistry as experienced clinicians usually will produce improved quality of clinical results, while less experienced or less competent clinicians might not volunteer to participate in the PBRN.

In terms of different implant designs and brands, this particular study had predominance representation by Nobel Biocare which affected the overall distribution of implants relative to the other implant designs and companies (Figure 4). If future studies were conducted to analyze different implant designs specific to implant companies, then attempts should be made to provide more evenly distributed use of
implant designs to provide accurate and more representative data. Moreover, the study did not document the specific type of implant abutment used which can influence soft tissue contour and papilla fill. The confounding variables were not evaluated or controlled which may skew the results, but given the small percentage of representation of these cases, the effect of these few cases would not change the outcome of the results presented.

Consideration not accounted also included the status of the adjacent natural tooth in terms of whether a restoration was present or not, what type of restoration was present or when it was done. This parameter could influence the emergence contour and position of the contact point which again may camouflage the shortened deficient papillae. Future studies should document the variable of the adjacent natural tooth to the implant to determine its role in support of the interproximal papilla between the implant restoration and natural tooth.

Moreover, the calibration of the peri-apical radiographs were determined by the actual known width of the implant diameter. However due to clinical limitations, distortions in the vertical dimension may have been different from that of the horizontal dimension. Therefore to improve the accuracy, the study could have taken into consideration the actual length of the implant and calibrated for the area of the implant, obtainable from the specific manufacturers and correct for possible radiographic distortions. In addition, in this study only two dimensional measurements were made of a 3-dimensional papilla and volumetric fill. Hence in order to improve the precision, future studies can use 3-dimensional volumetric determinations of the inter-dental papilla volume. Possible methods could include impression of casts, isolation of papilla by removal of adjacent teeth, and digitization of the above to obtain more accurate volumetric measurements.

The purpose of the study was to compare the 2 variables of vertical distance from crest of bone to contact point on the natural tooth and the horizontal distance from the platform of the implant to the natural tooth and to determine how these measures affected papilla formation. As the profession appreciates, this implant interface is a complex zone which has multiple variables that contribute to its final morphologic and aesthetic results. Therefore, future studies should be conducted
based on multivariate analysis of the interrelationship of all variables that contribute and impact this complex implant interface.

Although the mean values of the inter-dental-implant papilla from the crest of bone to contact point were approximately 5.0mm, it is interesting to note that the distal sites presented with a smaller standard deviation. This may be explained from a technical or anatomical perspective. The technical explanation may be due to the making of the radiograph not being directly perpendicular to the long axis of the implant and hence all measurements were skewed due to possible overlaps. This same phenomenon may also apply to the clinical photographs which may influence the assignment of the Jemt Papilla Index for interproximal papillae fill. The anatomical explanation may be due to the configuration contour of the adjacent natural root which may support the interproximal crest of bone which would provide support to the interproximal papillae. The natural curvature of the maxillary arch towards the distal may provide a wider dimension in the buccal palatal aspect of the interproximal crest of bone adjacent to the natural root, which again may provide enhanced support to the soft tissues. These are some of the suggested possible explanations for the results observed where the distal sites consistently seemed to show better interproximal papillae fill than the mesial sites. Further investigations and studies are required to determine if these explanations are valid or if other variables may contribute to this observed trend.

In light of the unpredictable nature and the multifactorial variables that influence the degree of presence or absence of the interproximal papilla, the following clinical protocol is recommended to achieve a more predictable clinical result. It is of the utmost importance to perform a comprehensive patient evaluation, clinical examination, diagnosis, prognosis with treatment options and planning for the anterior aesthetic implant in order to achieve optimal clinical success. An interdisciplinary approach involving prosthetics or restorative, oral surgery, periodontics, radiographic imaging and orthodontics are all required in an attempt to produce optimal clinical results. Appropriate selections for implant diameter, length, and surface and geometric implant design along with precise surgical implant placement to vertical depth and horizontal spacing to adjacent natural dentition will
increase chances of ideal clinical results. After a period of healing and the process of osseointegration has commenced, the only controlling factor would be the prosthetic phase, specifically the emergence contour, shape and contact location of the final and adjacent restoration. After second stage surgery, uncovering, and final impressions for the master cast, a direct-to-implant fixture screw retained provisional restoration should be fabricated. The soft tissue contour and profile should be allowed to be stabilized for a period of 6 months where the provisional can be altered to confirm its final contact location to eliminate the missing interproximal papilla (Jemt 1999, Grunder 2000, Choquet et al. 2001). The 6-month period will allow for creeping attachment that could occur between the time of provisional implant crown insertion and maturation of the adjacent gingiva (Choquet et al. 2001, Jemt 1997). At the provisional stage of treatment an arbitrary contact location can be created or altered to diminish the missing interproximal papillae area to reduce the likelihood of the development of inadequate papilla fill of the embrasure (a black triangle). Another custom impression coping can be fabricated to capture the defined soft tissue profile, location of the contact area and contour for the emergence profile for the master cast. The definitive final fixed implant restoration can be fabricated from the index of the provisional restoration to provide the detailed information required to ensure appropriate contact location that takes into account present morphological characteristics of the papilla present at that time. The final fixed implant crown can also be customized in terms of line angle locations along with shading or staining of the mesial or distal areas to camouflage and mimic the natural dentition. This approach would offer more precise predictability in terms of controlling for interproximal papilla fill rather than relying on empirical formulas that according to the data shown here do not apply to the specific patient or case with multiple variables.

Although all well-intended efforts and scientific knowledge along with meticulous clinical applications of various techniques are utilized to attempt to reproduce and mimic the anterior natural dentition, this challenging and complex area still remains unpredictable for the profession. Ideal final optimal aesthetics may not be achievable in some cases especially in patients presenting with compromised anatomical parameters. In light of these findings, it would be prudent to educate and
carefully evaluate the patient’s expectations, pre-existing anatomical conditions and treatment options prior to commencing these anterior aesthetic single implant cases. The patients’ goals should be realistic and based on the delivery of a full complement of information and match what is achievable clinically by the profession in these complex cases.

Conclusions

The fundamental hypothesis in the present study as supported by clinical observations was the degree of presence or absence for the inter-dental-implant papilla occurs irrespective of following clinical parameters reported in previous studies. Interpretation of the collected data revealed the results of our study and provides conclusive evidence to accept the null hypotheses: A) The vertical measurement from the crest of the bone adjacent to the natural dentition to contact point is not a reliable predictor for the presence of the inter-dental-implant papilla; B) The horizontal measurement from the platform of the implant to the adjacent tooth is not a reliable predictor for the presence of the inter-dental-implant papilla

Contrary to previously published data, our results show that when the vertical distance from the crest of the bone to the contact point on the natural tooth is <5.0 mm, and likewise, when the horizontal distance of implant platform to the adjacent tooth is >2.0 mm, these parameters are NOT predictable indicators for the presence of the interproximal papillae. Further investigations are required to determine the impact of the multiple specific variables, their interrelationships and their influence for the degree of presence of the interproximal papillae between an implant and natural tooth.
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Appendix I: Members of University of Toronto Dental Practice Based Research Network, and participants that actually submitted patient cases on the website (www.dentalpbrn.ca)
Members of PBRN bolded and boxed represents active participants who contributed data to this research project

**General Practitioners**

1) Dr. Mark Lin  
88 Finch Avenue East  
North York, Ontario M2N4R5  
416-221-8828

2) Dr. Natalie Wong  
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Scarborough, Ontario M1L 4S7  
416-285-8105

3) Dr. Al Kwong Hing  
CareChoice Dental Centres  
123 Edward Street, Suite 1515  
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4) Dr. Domenic Belcastro  
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416-924-3443

5) Dr. Simone Lin  
80 Finch Avenue West #203  
Toronto, Ontario M2N 2H4  
416-221-2195

6) Dr. Ian Erwood  
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905-447-6333

7) Dr. Michael Weinberg  
170 St. George St #810  
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416-920-8800

8) Dr. Morry Murad  
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Weston, Ontario M9P 3A9  
416-249-3957

9) Dr. Blake Niccolucci  
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519-472-7450

10) Dr. Rod Stewart  
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Markham, Ontario L3P 1Y8  
905-294-9905

11) Dr. Antonio Mancuso  
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Welland Ontario, L3C 3V7  
905-734-9901

12) Dr. Edward Philips  
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**Specialists**

**Prosthodontists**

1) Dr. Dennis Yokota  
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416-487-2848

**Periodontists**

2) Dr. Izchak Barzilay  
2300 Yonge Street, suite 905  
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416-322-6862

3) Dr. Don Sommerville  
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4) Dr. Bruce Glazer  
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5) Dr. Robert Carmichael  
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6) Dr. Vali Khadivi  
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416-222-3395

7) Dr. Neena D’Souza  
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Mississauga, Ontario L4Z 3W5

8) Dr. Robert Elia  
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Toronto, Ontario M2L 1K6  
416-512-6431

**Oral Surgeons**

9) Dr. Murray Arlin  
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Weston, Ontario M9P 3A9  
416-243-5215

10) Dr. Herbert Veisman  
25 Sheppard Avenue West, #1005  
Willowdale, Ontario M2N 6S6  
416-225-9910

11) Dr. Lesley David  
4292 Village Centre Court  
Mississauga, Ontario L4Z 1S2  
905-275-
Appendix II: Letter of invitation for members of Dental Practice Based Research Network (PBRN)

Dear Colleagues and friends:

You are cordially invited to participate to be a distinguished member of a University of Toronto based “Practice Based Research Network (PBRN).

As part of my Master of Science research thesis, we are establishing a network of members in private practice settings to contribute valuable clinical data for research purposes. As a member, your inputs and contributions will address relevant research questions and to participate in future prospective clinical trials that will further advance our profession as a whole. Further details were made available at a later time upon interest of participation from your dental practice.

As an inaugural pilot study, my research topic is on the topic of the “interproximal papillae adjacent to the single implant crown in the aesthetic zone”. The purpose of the study is to evaluate the clinical and radiographic evidence for the presence or absence of the interproximal papilla adjacent to the single implant tooth.

Data contribution and collection was streamlined to minimize disruption to your busy daily practice and can be delegated to your existing auxiliary team members. Specific to this project, see attached sample of the data required to be entered into our data management file at www.dentalpbrn.ca. Additional training was provided to your auxiliary team members to ensure standardization of data collection and entries.

Please indicate your level of interest and participation by e-mailing me directly at markhe.lin@utoronto.ca or calling me at 416-991-8828. I would strongly encourage you to consider joining as a member and participating with PBRN as you will directly help influence and contribute to the future of our dental profession.

I look forward to your feedback regarding this proposal in joining as a member of the PBRN and participating with my research thesis project.

Regards,

Mark Lin, B.Sc., D.D.S.
Appendix III: Patient consent for participation in research study

Dear Patient:

Your dentist is an active contributor to a Practice Based Research Network (PBRN) administered by the University of Toronto, Faculty of Dentistry, Prosthodontic discipline. Our member dentists are committed to advancing the art and science of clinical dentistry.

In a research study in which your dentist partakes, we wish to evaluate the aesthetic treatment outcome following single implant crown treatment. Since you have received this particular type of treatment, we respectfully ask that you consent to allowing your dentist to send us information about your particular treatment. Your anonymity will be completely secure since the information we ask for cannot be used to identify you as an individual, that is, so-called de-identified information.

Specifically, we request that your dentist is allowed to send us information about the local conditions in your mouth, details about the implant and crown components, as well as, details of the various steps of the implant treatment. Finally, we request a clinical photograph and radiograph limited to the actual implant location and a short survey on how satisfied you are with the aesthetic outcome of the implant treatment. We will not ask for any protected health information. Your dentist will be able to show you the form listing the information we ask for.

The de-identified information will only be available for the researchers at the Faculty of Dentistry and your own dentist.

Responsible for this PBRN research project is Dr. Asbjorn Jokstad, Head and Professor in Prosthodontics, and the primary investigator is Dr. Mark Lin. We are located in the Department of Prosthodontics, 124 Edward Street, phone 416 979 4930 ext. 4424. Feel free to contact us in case of concerns or requests for additional information.

I consent to my dentist submitting de-identified information about my treatment for this research study:

---------------------------- ---------------------------------------------------------------------
 Date       Name
Appendix IV: Dental Practice Based Research Network- Clinical data collection process

Instructions for Clinical Data Collection

Please recall the patients identified from the randomized protocol as instructed by the Co-Investigator (Dr. Mark Lin) and arrange a 1 hour appointment time slot. Confirm and have patient sign the consent form provided to participate in this research study.

1. Using a chart audit protocol, obtain the required information in the Clinical Data Collection (Appendix IV) for each of the selected patients to participate in the study.

2. Preparation of the operatory;
   a. Anterior RINN holder with 1 Periapical radiograph size # 2
   b. Gutta Percha of various different sizes depending on the size of the “black triangle” of the inter-dental-implant papillae.
   c. Digital camera
   d. Mouth Retractors
   e. Periodontal probe with millimetre markings and mouth mirror
   f. Patient’s Patient aesthetic evaluation postcard

3. Prepare to make the required photographs with digital camera and mouth retractors. Clinical digital or 35mm photograph taken at 1:1 magnification of area of interest. The photograph to be taken perpendicularly to the buccal surface of the single-tooth restoration crown. Make sure when making the photographs to air dry area of interest to be free of saliva, air bubbles or food debris.

A) Take a picture of the implant crown in center with natural dentition on either side

B) Take a full maximal “E” smile photograph with maximal gingival display, (Non retracted)
C) Take a frontal photograph, (retracted)

D) Try various sizes of gutta percha to make sure it fits interproximally to locate the tip of the interdental papillae on the mesial and distal locations.

E) Once the correct sizes have been chosen, cut it so the length is the same from facial to lingual aspect.

F) Place the RINN holder with the periapical # 2 film in the right position.

G) This photograph is only for instructional directions and NOT to be included as part of the data entry into the website.

H) Remove the retractors and maintain the same position and orientation.

Radiographic procedure:
I) Parallel long cone radiographic technique and a film holder (Rinn holder, DENTSPLY) for anterior Periapical radiograph size #2. Clinical photograph to follow same perspective or angle.

J) Different sizes of gutta percha cone sized to fit interproximal at the level of the tip of the interdental papilla to the tip of the papilla soft tissues radiographically.

K) The radiographs will be computer scanned, digitized, imaged and magnified for measurements.

L) Make a Periapical radiograph of the tooth and develop the film.

![Radiograph Image]

**Clinical procedure:**

i) Probing depths performed using a periodontal probe with standardized markings with 6 readings per implant restored tooth (MB, B, DB, ML, L, and DL).

ii) Soft tissue biotype: thick or thin

iii) Modified bleeding index

iv) Presence / absence of plaque

v) Gingival recession level

G) After DDS has completed the recall examination, record of the following items:

H) Scan or digitize radiograph and photographs to be uploaded to website. ([www.dentalpbrn.ca](http://www.dentalpbrn.ca))

I) Provide patient with instructions and directions for completion of the patient satisfaction survey postcard.

J) Thank and dismiss the patient.
### Appendix V: Dental Practice Based Research Network- Web site (www.dentalpbrn.ca) data entry and collection fields

#### Patient Data Collection

<table>
<thead>
<tr>
<th>Patient Name: ____________________</th>
<th>I.D. #: ____________________</th>
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<table>
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<tr>
<th>Y.O.B: ____________________________</th>
<th>Gender: M: _____ F: ______</th>
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</thead>
</table>

#### Smoking History: never: ________

If yes, please answer following questions:

- <10 cigs/day _____
- >11-20 cigs/day _____
- >21 cigs/day _____

- <1 year duration _____
- >1-5 year’s _____
- >5-10 year’s _____
- >11-20 year’s _____
- >20 year’s _____

### Past Diagnosis:

<table>
<thead>
<tr>
<th>Periodontal</th>
<th>Dental History: ____________________________</th>
</tr>
</thead>
</table>

#### Past Diagnosis:

#### Anterior Tooth Replacement Information

<table>
<thead>
<tr>
<th>Reason for tooth lost: ____________________</th>
<th>Trauma: _____ Failed RCT: _____</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetics: _____ Failed Rest: _____</td>
<td>Others: _________________________</td>
</tr>
<tr>
<td>Others: _________________________</td>
<td></td>
</tr>
</tbody>
</table>

#### Tooth position replaced with dental implant restoration:

<table>
<thead>
<tr>
<th>13</th>
<th>12</th>
<th>11</th>
<th>21</th>
<th>22</th>
<th>23</th>
</tr>
</thead>
</table>

#### Relevant Dates of Treatment Rendered

a) **Date of tooth extraction/loss:** ____________________

b) **Date of Implant placement:** ____________________

1. 1-stage surgery (placement of healing abutment at surgery): _____
2. 2-stage surgery (placement of cover screw at surgery): _____

c) **Date of uncovering or stage 2 surgeries:** ____________________

d) **Date of Insertion of Provisional or Temporary:** ____________________

Type of provisional: Fixed: _____

Removable: _____

Provisionalization loading protocol:

Immediate (same day as surgery): _____

Early (within 3 months): _____

Delayed (after 3 months): _____
<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>e) Date of final crown insertion:</td>
<td></td>
</tr>
<tr>
<td>Type: PFM:</td>
<td></td>
</tr>
<tr>
<td>All Ceramic:</td>
<td></td>
</tr>
<tr>
<td>Procera:</td>
<td></td>
</tr>
<tr>
<td>Alumina:</td>
<td></td>
</tr>
<tr>
<td>Zirconia:</td>
<td></td>
</tr>
<tr>
<td>Cercon:</td>
<td></td>
</tr>
<tr>
<td>Others:</td>
<td></td>
</tr>
<tr>
<td>Implant crown retention:</td>
<td></td>
</tr>
<tr>
<td>Screw retained:</td>
<td></td>
</tr>
<tr>
<td>Cement retained:</td>
<td></td>
</tr>
<tr>
<td>f) Date of recall exams:</td>
<td></td>
</tr>
<tr>
<td>g) Duration in function:</td>
<td></td>
</tr>
</tbody>
</table>

### Implant Information

| Implant Company Name: |          |
| Implant Brand name:   |          |
| Implant diameter:     |          |
| Implant diameter at platform: |          |
| Implant length:       |          |
| Platform switching protocol utilized: Yes: |        |
|                       | No:      |