4-year radiographic & esthetic evaluation of peri-implant tissue in immediate implants replacing single teeth in the esthetic zone

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Abstract

THERESA C. WANG: 4-year radiographic & esthetic evaluation of peri-implant tissue in immediate implants replacing single teeth in the esthetic zone (Under the direction of Lyndon F. Cooper D.D.S., Ph.D., Gustavo Mendonca D.D.S., Ph.D., Salvador Nares D.D.S., Ph.D.)

It is suggested that encroachment of the implant-abutment interface (IAI) to the existing tooth (< 1.5mm), negatively affects bone levels. As bone is the foundation for soft tissue, changes in bone levels may influence the overall esthetic outcome. The first part of this thesis details a study on 44 dental implants placed in 38 patients. Periapical radiographs and dental photographs were evaluated at 1 and 4 year/s to assess interproximal bone levels and pink esthetics. Current data assessed failed to indicate a relationship between IAI – tooth distances and bone changes at 4 years. Data suggest that there is no correlation between proximity of dental implant to adjacent tooth and interproximal soft tissue fill. Data also suggest that crestal bony changes following immediate dental implant placement do not have any relationship with soft tissue esthetics. Further investigations are necessary to examine soft and hard tissue architecture and their influence on esthetics. The second part of this paper consists of a comprehensive review discussing the multi-factorial nature of dental implant esthetics.
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Part II

Fig 1. Study Selection Procedure
Abstract

Interproximal bone levels are major determinants of implant esthetics. It is suggested that encroachment of the implant-abutment interface (IAI) to the existing tooth (< 1.5mm), negatively affects bone levels. The objective of this study is to compare the crestal bone and esthetic outcome of dental implants replacing single teeth in the esthetic zone at 1 year versus 4 years. Two calibrated examiners evaluated 44 implants. Data was obtained from patients (n=38) enrolled in a prospective clinical trial with an immediate provisionalization protocol. Bone levels were measured from IAI on periapical radiographs using digital methods. Pink Esthetic Scores (PES) were assigned using digital dental photography. Mean mesial and distal change in bone was 0.20 ±1.00 mm and 0.20 ±0.74 mm respectively. Current data fails to indicate a relationship between IAI-tooth distances and crestal bone changes at 4 years. There is a statistically significant (p<0.001) relationship between smaller IAI-tooth distances and lower PES. However, data suggests that there is no correlation between either IAI-tooth distances and interproximal soft tissue fill. Further investigations are necessary to examine the multifactorial nature of soft and hard tissue architecture surrounding dental implants.
Background

A missing front tooth has a profound effect on the social and psychological health of an individual (Elias & Sheiham 1998; Abu Hantash et al. 2006). When replacing a front tooth, not only does the esthetic result matter, but it also becomes the critical factor in determining whether treatment can be considered successful. This most often applies to the maxillary anterior dentition, which is visible during daily function and social activities. Fixed tooth replacement in the esthetic zone is not only important for self-esteem but also associated with social perceptions of an individual’s well being (Burkhardt et al. 2000; Willis et al. 2008).

Unarguably, dental implant therapy has become the favored treatment option for single tooth replacement within recent years. Systematic reviews have demonstrated that the 10-year survival rate of the single tooth dental implant is comparable to the survival rate of a three unit fixed partial denture (Pjetursson et al. 2007). Outstanding success and survival rates from several long-term human clinical control trials have facilitated the progressive development of dental implant components and treatment protocols that have improved our efficiency and treatment capabilities (Jung et al. 2008; den Hartog et al. 2008). Furthermore, single maxillary implants have been immediately restored with high survival rates ranging from 96-100%, allowing the clinician to provide immediate esthetic results.
(Chen et al. 2004; DeKok et al. 2006; Lindeboom et al. 2006). Thus, the increasing demand for and use of dental implants in the replacement of missing anterior teeth underscores the importance of understanding and managing the various parameters that influence the esthetic outcome.

In addition to matching the implant crown to the neighboring dentition, the peri-implant soft tissue should blend naturally with that of the surrounding teeth (Kan et al. 2003; Meijer et al. 2005). In the esthetic zone, clinical success is highly dependent on achieving long-term soft tissue results (Belser et al. 1998; Kan et al. 2003). Not only do clinicians have to consider existing tissue architecture, they must be mindful of the surgical positioning of the implant and subsequent remodeling process of the bone (Cardaropoli et al. 2006). Increasing understanding about the nature of soft tissue and biological width have facilitated the practitioners’ ability to utilize dental implant therapy more predictably in esthetic regions (Tarnow et al. 1992; Zetu & Wang 2005; Martegani et al. 2007). Animal studies have demonstrated that the peri-implant mucosa that forms around titanium implants, following abutment connection, have common features with the gingiva around natural teeth (Berglundh et al. 1991). These features include the components to biologic width: connective tissue, junctional epithelium and sulcular depth (Herman et al. 2000). In addition, studies have shown that a 4 mm height is established around the transmucosal part of the implant fixture (Abrahamsson et al. 1996; Berglundh & Lindhe 1996; Choquet et al. 2001). Therefore, placement protocols allowing reestablishment of biological width and maintenance of
natural soft tissue contours will maximize esthetic results (Evans & Chen 2008; Cooper 2008).

Various approaches have been employed to maximize marginal tissue maintenance including hard and soft tissue augmentation, immediate placement protocols, and the use of implants with various configurations that promote the sustainability of tissue (Meijndert et al. 2007; Morris et al. 2004; den Hartog et al. 2008, Stein et al. 2009; Sanz 2009). Furthermore, dental implant components that promote natural visual results, such as ceramic custom abutments, have been employed (Ekfeldt et al. 2011). Other modifications to components, including surface technology to promote cell adhesion, have also been proposed (Nevins et al. 2008). Regardless of the techniques used to maximize marginal tissue, the underlying architecture must be present and biology must be respected to optimize our esthetic goals.

Critical horizontal and vertical dimensions have been described by authors in regards to proper implant positioning adjacent to teeth and implant fixtures. Buccal-lingual and mesial-distal dimensions have been thought to influence the subsequent bone remodeling process (Esposito et al. 1993). Grunder and colleagues (2005) considered an intact buccal plate as a significant factor in esthetic success. However, this has not been confirmed, as there are not any studies comparing the buccal plate thickness and esthetic result (Teughels et al. 2009). In the mesial-distal dimension, guidelines are different for implants placed adjacent to natural teeth versus an implant fixture. It is suggested that implants should be positioned at least 1.5 mm away from an adjacent tooth and there should not be less than 3 mm between two implants to
minimize crestal bone loss (Buser et al. 2004). Single implant cases benefit from the hard and soft tissue of adjacent dentition. It has been determined that the interproximal bone of a tooth-bound dental implant is dependent on the level of bone at the adjacent tooth (Avivi-Arber & Zarb 1996; Grunder et al. 2000). Thus, it is stipulated that the presence of papillae is primarily influenced by the interproximal bone level of the adjacent tooth (Jemt et al. 1997; Choquet et al. 2001; Kan et al. 2003; Cardaropoli et al. 2006). Finally, many studies indicate that the interproximal tissue volume increases following crown placement, but the buccal tissue tends to diminish during the first year (Jemt & Lekholm 2003; Cardaropoli et al. 2006; Raes et al 2011). We therefore cannot rule out the influence of the remodeling process that occurs following tooth extraction and surgical trauma (Gargiulo et al. 1961).

A recent systematic review determined that previous studies suggest that a 3 mm interproximal distance from fixture to adjacent tooth is maintained to increase the likelihood of papillary fill (Teughels et al. 2009). However, the authors state that these conclusions were based on older implant types that had been characterized with saucerization. Consequently, there is a need for new data to confirm whether these suggested horizontal critical dimensions still apply to current dental implants. The purpose of this study is to investigate the interproximal bone dimensions in relationship to objective measures of esthetics. The specific aims of this project entails: (1) Evaluating the crestal bone changes and distance between implant fixture and adjacent tooth (2) Assessing the esthetic outcome using digital dental photographs and the Pink Esthetic Score (PES) described by Furhauser et al. in 2005, (3) Determining
whether (a) proximity of fixture to tooth is related to crestal bone changes, (b) proximity of fixture to tooth is related to soft tissue esthetics (c) crestal bone changes are related to soft tissue esthetics.
Materials and Methods

Patient Selection
This study included subjects that were enrolled in a longitudinal prospective clinical trial at the University of North Carolina School of Dentistry. The study was approved by the University of North Carolina Institutional Review Board (IRB) and informed consent was obtained from all subjects. All patients were non-smokers and healthy (without systemic disease). The treatment modalities for implant placement (Astra Tech, Osseospeed, Mölndal, Sweden), provisionalization, and final crown delivery are described in detail in a previous publication (Cooper et al. 2010). A total of 44 subjects with 56 implants were assessed for inclusion in this observational radiographic and photographic study. Due to poor image quality or incomplete data, 38 subjects with 44 implants were included for the final analysis.

Analysis of Radiographs
Peri-apical radiographs were taken using the long cone parallel technique to evaluate the interproximal marginal bone level. Periapical radiographs are currently regarded as the standard technique to evaluate interproximal bone, as CBCT software improvements are necessary to accurately measure bone around dental implants (De Smet et al. 2002; Raes et al. 2011). Bone levels were assessed at 1 year and 4 year follow up. All radiographs were digital, and measurements were made
using Image J image processing software (National Institute of Health). All radiographs were calibrated using the known implant diameter as a reference. The implant abutment interface (IAI) was chosen as a reference point, as it was easily recognized. The distance between the reference point to the crestal bone level (My, Dy) and adjacent tooth (Mx, Dx) was measured in millimeters at the mesial and distal of each implant using magnification (x7) to the nearest .01 mm (Figure 1). Two independent examiners not related to the patients’ treatment analyzed all radiographs.

Fig 1. Radiographic measurements were made from the Implant-abutment-interface (IAI) on both the mesial and distal aspects of the fixture.
Analysis of Photographs

Intraoral digital photographs were used to assign Pink Esthetic Scores (PES) at 1 year and 4 year follow up (Furhauser et al. 2005). PES is composed of 7 parameters that can be scored 0-1-2, with 2 being the best and 0 being the worst score (Figure 2). Papillae are evaluated for completeness, and the other variables are assessed by comparison with a reference tooth. Cosyn and collegues (2010) defined a PES score of equal or less than 7 to be an esthetic failure, greater than 8 to be acceptable, and greater or equal to 12 to be almost perfect. PES were recorded by two calibrated independent examiners not involved in any treatment. All photographs were scored twice with an interval of 1 week.

Fig 2. 1 year and 4 year results were scored using the Pink Esthetic Score (Furhauser et al. 2005) composed of 7 subcategories with a minimum score of 0 and maximum score of 14.

<table>
<thead>
<tr>
<th>Variables</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesial papilla</td>
<td>Shape vs. reference tooth</td>
<td>Absent</td>
<td>Incomplete</td>
</tr>
<tr>
<td>Distal papilla</td>
<td>Shape vs. reference tooth</td>
<td>Absent</td>
<td>Incomplete</td>
</tr>
<tr>
<td>Level of soft-tissue margin</td>
<td>Level vs. reference tooth</td>
<td>Major discrepancy &gt;2 mm</td>
<td>Minor discrepancy 1-2 mm</td>
</tr>
<tr>
<td>Soft-tissue contour</td>
<td>Natural, matching reference tooth</td>
<td>Unnatural</td>
<td>Fairly natural</td>
</tr>
<tr>
<td>Alveolar process</td>
<td>Alveolar process deficiency</td>
<td>Obvious</td>
<td>Slight</td>
</tr>
<tr>
<td>Soft-tissue color</td>
<td>Color vs. reference tooth</td>
<td>Obvious difference</td>
<td>Moderate difference</td>
</tr>
<tr>
<td>Soft-tissue texture</td>
<td>Texture vs. reference tooth</td>
<td>Obvious difference</td>
<td>Moderate difference</td>
</tr>
</tbody>
</table>
**Statistical Analysis**

Inter- and intra- examiner reliability was tested by computing Cronbach Coefficient Alpha with 0.70 as an acceptable reliability coefficient. Mesial and distal bone loss around the implant was calculated, and the relationship between bone loss and the distance between the implant and the tooth was tested by general linear model regression. PES scores at 1 year and 4 year follow-up were calculated and compared by paired T-test. The associations between radiographic bone level measurements and PES scores were further explored by using the Pearson Chi-square test and linear regression modeling. SAS ODS (output delivery system) statistical graphics were used to generate the plots. All statistical analyses were performed using SAS version 9.2 (SAS, Cary, NC) with 0.05 as significant level.
Results

Intra/interexaminer Reliability
Near perfect interexaminer agreement was confirmed using the Cronbach Coefficient Alpha Test for the radiographic measurements ($\alpha=0.98$). PES also demonstrated near perfect inter- and intra- examiner agreement using the Cronbach Coefficient Alpha test ($\alpha=0.98$).

Description of Sample
In total, 56 implants sites in 44 subjects were eligible for evaluation. 2 patients were lost to follow up and 16 were not included due incomplete data or poor image quality. 44 implant sites in 38 subjects provided adequate data for analysis. From this cohort, there were not any implant failures or complications reported.

Radiographic Analysis
Mesial and distal bone loss measured from radiographs over 3 years were 0.2mm (SD= 1.00) and 0.2mm (SD=0.74) respectively. Regression analysis failed to reject the null hypothesis that there is no relationship between proximity of tooth to implant and change in crestal bone level (Fig 3, 4).
Fig 3. Mesial proximity of fixture to tooth vs. change in bone level (p = 0.8360).
Fig 4. Distal proximity of fixture to tooth and change in bone level (p=0.0888).
Photographic Analysis

Table 1 demonstrates the mean PES subcategories at 1 year and 4 years. Mean PES increased from 10.80 (SD=1.79) at 1 year to 10.88 (SD=2.14) at 4 years follow up. At 1 year 30% of patients scored near perfect, 68% were considered acceptable, while only 2% were considered esthetic failures. Similarly, at 4 years 45% of patients scored near perfect, 48% were considered acceptable, while only 7% were considered esthetic failures. The changes were not found to be statistically significant (Figure 5).

Table 1 PES subcategory average scores ± SD at 1 year and 4 year.

<table>
<thead>
<tr>
<th>PES Subcategories</th>
<th>1 year</th>
<th>4 year</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>M papilla</td>
<td>1.48±0.64</td>
<td>1.4±0.63</td>
<td>-0.08±0.62</td>
</tr>
<tr>
<td>D papilla</td>
<td>1.60±0.55</td>
<td>1.4±0.67</td>
<td>-0.20±0.46</td>
</tr>
<tr>
<td>Level</td>
<td>1.78±0.48</td>
<td>1.73±0.45</td>
<td>-0.05±0.45</td>
</tr>
<tr>
<td>Contour</td>
<td>1.55±0.50</td>
<td>1.58±0.55</td>
<td>0.03±0.58</td>
</tr>
<tr>
<td>Alveolar bone</td>
<td>1.78±0.42</td>
<td>1.78±0.42</td>
<td>0±0.51</td>
</tr>
<tr>
<td>Color</td>
<td>1.20±0.46</td>
<td>1.43±0.50</td>
<td>0.23±0.48</td>
</tr>
<tr>
<td>texture</td>
<td>1.43±0.50</td>
<td>1.58±0.50</td>
<td>0.15±0.62</td>
</tr>
<tr>
<td>TOTAL PES</td>
<td>10.80±1.79</td>
<td>10.88±2.14</td>
<td>0.08±1.82</td>
</tr>
</tbody>
</table>
Fig 5. Box plot of mean PES score and distribution at 1 year and 4 year follow up.

**Bone levels and PES**

Interestingly, the proximity of the fixture to the tooth from both mesial and distal is significantly associated with PES (p<.0001). The data suggests that the closer the fixture is to the tooth, the lower the PES (Figure 6, 7). Change in bone level over 3 years on the distal side of the fixture is significantly associated with PES (p=0.004). However, this relationship was not identified from the mesial aspect of the fixture (Figure 8, 9). Regression analysis showed that more bone loss on the distal side of the fixture correlated with a lower PES.
Fig 6. Mesial proximity of fixture to tooth vs. PES (p<0.0001).
Fig 7. Distal proximity of fixture to tooth vs. PES (p<.0001).
**Fig 8.** Mesial change in bone level vs. PES (p=0.0515).
Fig 9. Distal change in bone level vs. PES (p=0.0040).

**Radiographic measurements and papilla fill**

We further explored the association between bone measurements and papilla score. In contrast to our findings regarding proximity of implant fixture to tooth and total PES, regression analysis showed no association between the proximity of the dental implant to tooth and individual papilla scores (Figure 10, 11). The changes in bone level (Δy) did not show a correlation with individual papilla scores, either (Figure 12, 13). Although the total PES is significantly related with the proximity of fixture to tooth, this relationship is not found at the subcategory level for papilla score. Other subcategories in PES may have contributed to the result. Thus, the relationship between proximity of fixture to tooth and esthetic result is still unclear.
Fig 10. Mesial change in bone level vs. mesial papilla score (p=0.6317).
Fig 11. Distal change in bone level vs. distal papilla score (p=0.1842).
Fig 12. Mesial proximity to tooth vs. mesial papilla score (p=0.9042).
**Fig 13.** Distal proximity to tooth vs. distal papilla score (p=0.0545).
Discussion

The survival rate for the implants included in this study was 100% (38/38) which is in accordance with the survival rates of other studies that had utilized an immediate provisionalization protocol (Kan et al. 2011; DeKok et al. 2006).

The data indicates that the mean change in bone level (0.20 mm) on both aspects of the fixture was consistent with those found in previous studies (Engquist et al. 2002; Wennstrom et al. 2005). Furthermore, bone levels reported are well within the parameters of success criteria described by Albreksson and colleagues (1986).

According to recent systematic reviews, there is a lack of literature using esthetic indices (den Hartog et al. 2008; Teughels et al. 2009). Currently, there are a few esthetic measurement systems that have been proposed. The Pink Esthetic Score (PES) was used in this study and assesses the soft tissue exclusively (Furhauser et al. 2005). The Implant Crown Aesthetic Index described by Meijer and colleagues in 2005 evaluates the crown and the mucosa. More recently, the White Esthetic Score (WES) was described by Belser and colleagues (2009) and has been used in conjunction with the PES for a more complete esthetic outcome analysis. In this study, using the PES to measure esthetics objectively and consistently allowed us to evaluate overall esthetic success of our study group. At the 4 year follow up, 93% of our samples had PES with
acceptable to near perfect result (8-14) with only 7% considered failures (≤7). Mean PES for this study at 1 and 4 years were 10.80±1.79 and 10.88 ±2.14 respectively. This is similar to results published by Raes and colleagues (2011) that examined immediately loaded dental implants in the esthetic zone. Other studies using PES have demonstrated PES with almost perfect scores (≥12) in 19-39% of the cases (Juodzbalys and Wang 2007; Chen et al. 2009; Cosyn et al. 2010, Raes et al. 2011). In this study, cases with almost perfect PES scores were demonstrated in 45% of the subjects, which is slightly higher than previous reports. Our results also demonstrated that the PES at the two different time points was found to not be statistically significant. This could be due to the fact that after 1-1.5 years following surgical intervention, remodeling of the soft tissues has typically stabilized (Johnson et al. 1969; Gargiulo et al. 1961).

Regarding fixture to tooth distance and vertical bone loss, our findings are in agreement with a 3-year retrospective study that reported a lack of relationship between inter-unit distance and longitudinal marginal bone loss (Cardaropoli 2003). Esposito and colleagues (1993) described increased bone loss at the tooth with decreased distance to the implant between the time of implant placement and final crown placement. Since this study did not assess the radiographs at these time points, our study results cannot be compared directly to this previous report.

Interestingly, our results indicate that implant to tooth distances and PES on both mesial and distal aspects of the fixture were correlated negatively (p<0.001). This result, however, was not due to the mesial and distal papilla fill, as there was not a
significant relationship established between implant to tooth distances and papilla subscores. Furthermore, there was not a relationship established between changes in crestal bone level and papilla subscores. These finding can be explained by the fact that PES is composed of 7 subscores that assess various factors contributing to pink esthetics. Aside from papilla fill, there are also scores for level of soft tissue margin, tissue contour, alveolar process, color, and texture. Since PES is an evaluation of the soft tissue complex as a whole, the lower score may be indicative of predisposing factors, such as existing tissue anatomy or general remodeling issues that may be associated with a smaller edentulous space. Furthermore, surgical finesse in the placement of the fixture in smaller edentulous space may influence esthetic results. If the placement alters other factors, such as the level of the zenith, then the overall esthetic result may be compromised. In contrast to our results, reports by Lops and colleagues (2011) examining the same implant fixture found that when inter-implant tooth distances were 2.5-4 mm, the interproximal papilla was present 92.8% of the time. They also identified that with a distance less than 2.5 mm the papilla was absent 70% of the time. Authors recognize that there was only an interaction between horizontal and vertical distances when the spacing was greater than 2.5 mm.

Finally, our results also indicated that there was a significant relationship between bone loss and PES score on the distal aspect of the fixture but not on the mesial aspect. Previous reports have demonstrated more bone loss on the distal aspect of the fixture (Norton et al. 2006). Notably, a recent study by Raes et al. (2011) found that the distal papilla was more delicate to maintain, especially in immediate implant
therapy. The reason for this is unclear and a larger sample size with a comprehensive evaluation of sample characteristics may contribute to our understanding of this finding.

It is worth mentioning that the implants used for this study have a connection that has an under-dimensioned abutment when compared to fixture diameter. It has been postulated that this type of connection moves the inflammatory infiltrate that is present at the implant abutment junction away from the bone (Lazzara et al. 2006). The microgap has been investigated in animal studies, and authors concluded that it is the stability of the interface rather than the size of the microgap that influences bone loss around dental implants (Herman et al. 2001; King et al. 2002). Furthermore, Cardaropoli and colleagues (2005) examined non-platform switched implants and had similar results in regard to bone loss. The influence of the implant abutment interface still needs further examination.

Our study does not demonstrate a relationship between IAI–tooth distances and crestal bone changes at 4 years. However, there is a statistically significant (p<0.001) relationship between smaller IAI-tooth distances and a lower PES. It must be recognized that the proximity of fixture to tooth was found to be unrelated to papilla fill. In addition, vertical changes in bone level did not influence interproximal soft tissue fill. Our results highlight the multifactorial nature of soft and hard tissue surrounding dental implants. Many factors including the surgical procedure, prosthetic management, and choice of implant components may contribute to ultimate esthetic
success. More data is needed in regards to using objective criteria in evaluation of esthetic success.
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Lindeboom JA, Frenken JW, Dubois L, Frank M, Abbink I, Kroon FH. Immediate loading versus immediate provisionalization of maxillary single-tooth replacements: a


Part II: The roles of tissue architecture, surgical procedures, implant components and prosthetic decisions on the esthetic outcomes of single tooth implants in the esthetic zone: a comprehensive review.

Abstract

Objective: The purpose of this review was to examine how tissue architecture, surgical procedures, implant components and prosthetic factors contribute collectively to esthetic success in the maxillary anterior and premolar region (esthetic zone).

Materials and methods: Pubmed, Embase and the Cochrane electronic databases were searched for prospective human studies that investigate single tooth implants placed in the esthetic zone. Two reviewers assessed the quality of search results independently. The outcomes assessed include implant survival, complications, and peri-implant soft and hard tissue characteristics. Peri-implant soft tissue assessment included probing depths, bleeding on probing, plaque index, keratinized tissue and papilla index. Hard tissue assessment included measurements made at the time of surgical procedures and radiographic analysis. Studies that measured esthetic outcomes utilizing esthetic indexes and self-report were also included.

Results and discussion: Of 51 primarily selected articles, 13 studies fulfilled the inclusion criteria. A variety of predictors for esthetic success were evaluated, such as existing hard and soft tissue architecture, the effect of simultaneous soft and hard tissue augmentation, the use of different implant components and various restorative protocols. These factors ultimately influence the final esthetic success in
a collective manner. However, the results of this review suggest that there is not a standardized measure of esthetic success in dental implant therapy.

**Conclusions:** The literature included in this review suggests that implant esthetic success is multi-factorial. Importantly, soft and hard tissue architecture plays an essential role for the esthetic success of dental implants in the esthetic zone. Although there is a lack of well-designed controlled clinical trials that infer certain interventions produce better treatment outcomes, clinicians may improve esthetic success with adequate architectural assessment followed by choosing the appropriate surgical procedures and implant components that may enhance results.
Background

The progressive nature of dental implants treatment has been facilitated by outstanding survival rates from several long-term human clinical control trials (Jung et al. 2008, den Hartog et al. 2008). This has been accompanied by the establishment of treatment guidelines, improvements in surgical protocol, and the development of innovative implant components and surface technologies that have contributed to improving the quality of care in dental implant treatment (Belser et al. 2007, Shalabi et al. 2006).

Through systematic review, it has been demonstrated that the 10-year survival rate of single tooth dental implant replacement is comparable to the survival rate of a three unit fixed partial denture (Pjetursson et al 2007). Dental implant treatment has been regarded as the most conservative and biologic treatment modality in the replacement of single anterior teeth (Pjetursson et al 2008). Furthermore, advances in bone and soft tissue augmentation procedures and increasing understanding about the nature of soft tissue and biological width have facilitated the practitioners’ ability to utilize dental implants more predictably in highly esthetic regions (Tarnow et al. 1992, Zetu and Wang 2005, Martegani et al 2007). It is clear that dental implant therapy has become the favored treatment option for single tooth replacement within recent years.
Esthetic concerns apply when the implant restoration and the surrounding soft tissues are visible during daily functional activities and in social settings. The increasing use of dental implant therapy to replace missing teeth in the esthetic zone underscores the importance of evaluating esthetic success. However, scientific literature describing reproducible esthetic parameters is considerably insufficient (Belser et al. 2004). In the esthetic zone, success is highly dependent on the long-term esthetic results that can be achieved. Optimally, the goal is to match the peri-implant soft tissue with the soft tissue of the adjacent natural teeth; the implant crown should blend naturally in size, contour and shape with the adjacent teeth (Meijer et al. 2005).

Yet, the most unpredictable determining factor in establishing esthetics is peri-implant soft and hard tissue support. Not only do clinicians have to consider existing tissue architecture, another important factor is the surgical positioning of the implant and subsequent remodeling process of the bone (Cardaropoli et al. 2006).

Various approaches have been utilized to maximize esthetic outcomes including hard and soft tissue augmentation, utilizing implants with various configurations that promote the sustainability of tissue and immediate loading protocols (Meijndert et al. 2007, Morris et al. 2004, den Hartog et al. 2008). Because the presence and characteristic of soft tissue is highly dependent on underlying bony structure, recent investigations have been conducted in order to establish dimensional guidelines to optimize esthetic success (Huynh-Ba et al. 2010, Tomasi et al. 2010). It is valuable for clinicians to be able to evaluate an edentulous site in the esthetic zone and understand the various components that contribute to the esthetic outcome. Thus, the objective of
this study is to discuss the interplay of the multiple factors that contribute to implant esthetic success in the esthetic zone.
Materials & Methods

Types of studies
All prospective human clinical trials of dental implants replacing single teeth in the esthetic zone were considered for this review. Study designs included randomized control trials, controlled trials, randomized trials and prospective cohort studies. Retrospective studies were not included. No time limitations were implemented. Language was restricted to papers published in English.

Types of participants
Patients included were treated with an implant-retained single tooth replacement in the esthetic zone, neighbored by natural teeth. The esthetic zone is defined as: anterior and premolar maxillary teeth; as smile line and gingival display vary in individuals. This is the objective definition given by the ITI Treatment Guide (Belser et al. 2007).
Interventions

The factors examined in the articles being reviewed can be grouped into the following categories:

A. Anatomical considerations

B. Surgical interventions
   1) Early versus delayed implant placement (Gotfredsen et al. 2004)
   2) Simultaneous hard tissue augmentation and implant placement
      i. Type of grafting material (Meijndert et al. 2007)
      ii. Graft versus no graft (Chen et al. 2007)

C. Implant components
   1) Type of implant
      i. Cylinder versus taper (Sanz et al. 2009)

D. Prosthetic decisions
   1) Loading protocols
      i. Immediate versus delayed load in a flapless surgical approach (Oh et al. 2008)
      ii. Immediate versus conventional loading in a standard surgical approach (Hall et al. 2007)
      iii. Immediate loading versus immediate provisionalization without load in a standard surgical approach (Lindeboom et al. 2006)
      iv. Immediate placement and provisionalization (De Rouck et al. 2008)
      v. Immediate provisionalization versus submerged in an immediate placement approach (De Rouck et al. 2009)
**Outcome measures**

- Implant survival, defined as the presence of the implant at the time of follow-up
- Complications: biological and technical
- Changes in marginal bone level assessed by radiographs
- Assessment of peri-implant structures
  - Papilla Index (Jemt et al. 1997)
  - Probing depth, plaque index, bleeding on probing
- Aesthetic indexes
  - Pink Esthetic Score (Furhauser et al. 2005)
  - Implant Crown Esthetic Index (Meijer et al. 2005)
- Patient satisfaction/self-evaluation of esthetics
- Measurements of bony architecture at time of extraction, implant placement or second stage surgery

**Search strategy**

This review consisted of a search of the literature utilizing PUBMED and EMBASE and was supplemented with a search of systematic reviews in the Cochrane Central Register of Controlled Trials (CENTRAL).

The searches were conducted using MeSH terms: "Dental Implants"[Mesh] OR "Dental Implants, Single-Tooth"[Mesh] AND "Esthetics"[Mesh] OR "Esthetics, Dental"[Mesh] and free text words “implants and esthetics”. In addition, references of relevant review articles were examined to identify additional publications.
Two examiners scanned the titles and abstracts found in the search. Full-text articles were obtained and examined by two independent reviewers.

**Quality assessment**

All studies that were not relevant to the topic in review were not included for full text analysis. For example, studies examining dental implants replacing multiple missing teeth, with dentures or fixed partial dentures as ultimate prosthesis, were excluded. Those examining posterior teeth and studies with improper study design were not included. Following full-text analysis, methodological quality was assessed (Table 1).

**Data extraction and analysis**

The article selection process included screening of the titles and abstracts by two independent reviewers (L.C. and T.W.). A full-text screening followed, the data was extracted by the reviewers and recorded in a data extraction sheet. Meta-analysis was not feasible due to the heterogeneity of the studies and outcome variables.
Table 1: Studies excluded after quality assessment and reasons for exclusion.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study design</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cochran et al. (2009)</td>
<td>Prospective Multicenter Human Clinical Trial</td>
<td>Not exclusive to esthetic zone, not exclusive to single tooth</td>
</tr>
<tr>
<td>Martegani et al. (2007)</td>
<td>Prospective Multicenter Human Clinical Trial</td>
<td>Evaluates natural teeth, not implants</td>
</tr>
<tr>
<td>Sunitha et al. (2008)</td>
<td>Prospective Human Clinical Control Trial</td>
<td>Not exclusive to esthetic zone</td>
</tr>
<tr>
<td>Bianchi et al. (2004)</td>
<td>Prospective Human Randomized Clinical Control Trial</td>
<td>Not exclusive to esthetic zone</td>
</tr>
<tr>
<td>Lee &amp; Hasegawa (2008)</td>
<td>Prospective Human Clinical Trial</td>
<td>Small sample size, too many variables</td>
</tr>
<tr>
<td>Yilmaz et al. (1998)</td>
<td>Prospective Human Clinical Control Trial</td>
<td>Not exclusive to single tooth</td>
</tr>
<tr>
<td>Johnson &amp; Persson (2001)</td>
<td>Prospective Human Clinical Trial</td>
<td>Sites included not specified</td>
</tr>
<tr>
<td>Kemppainen et al. (1997)</td>
<td>Prospective Human Randomized Clinical Trial</td>
<td>Not exclusive to esthetic zone</td>
</tr>
<tr>
<td>Morris et al. (2004)</td>
<td>Prospective Multicenter Human Clinical Trial</td>
<td>Not exclusive to esthetic zone</td>
</tr>
<tr>
<td>Zembic et al. (2009)</td>
<td>Prospective Human Randomized Clinical Control Trial</td>
<td>Posterior teeth evaluated</td>
</tr>
<tr>
<td>Sailer et al. (2009)</td>
<td>Prospective Human Randomized Clinical Control Trial</td>
<td>Posterior teeth evaluated</td>
</tr>
<tr>
<td>Sethi et al. (2000)</td>
<td>Prospective Human Clinical Trial</td>
<td>Sites included not specified, not exclusive to single tooth</td>
</tr>
<tr>
<td>Kastenbaum et al. (1998)</td>
<td>Prospective Human Clinical Trial</td>
<td>Not exclusive to esthetic zone, not exclusive to single tooth</td>
</tr>
<tr>
<td>Malo et al. (2003)</td>
<td>Prospective Multicenter Human Clinical Trial</td>
<td>Not exclusive to esthetic zone, does not evaluate esthetics</td>
</tr>
</tbody>
</table>
Fig 1. Study Selection Procedure

**Identified articles: 51**
- Pubmed
- Embase
- Cochrane

**Excluded articles**
- Non-topic related
- Improper study design
- Animal studies

**Included for full text analysis: 27**

**Excluded articles**

**Articles included for review: 13**
Results

Implant Survival and Success

Of the selected articles, authors that reported on survival considered the presence of the implant at follow-up as survival and followed the criteria for successful osseointegration proposed by Smith and Zarb (1989).

Gotfredsen and colleagues (2004) reported 100% implant survival rate for both their “early” (4 weeks following extraction) and conventional placement groups.

Meijndert et al. 2007 performed conventional placement with bone augmentation. All of their cases were grafted with an autogenous chin graft or xenograft (BioOss®) and resorbable collagen membrane. They had two implants that were mobile at the start of the prosthetic procedures, and thus did not include them for aesthetic evaluations. However, these authors were able to successfully re-operate with reimplantation and bone augmentation.

In a flapless approach, Oh and colleagues (2006) reported that at 6 months, they achieved a survival rate for delayed load and immediate load implants at 100% and 75%, respectively. Interestingly, all failures in their immediately loaded group were in the premolar region.

The literature suggests that immediately placed implants without grafting have demonstrated predictability as a treatment approach (Chen et al. 2007; Ferrus et al. 2010; Huynh-Ba et al. 2010, Tomasi et al. 2010; Sans et al. 2010). Furthermore,
implants that were provisionalized, in both immediately and conventionally placed implants, yielded excellent survival of 96-100% at 1 year follow up (Hall et al. 2007; Lindeboom et al. 2006, De Rouck et al. 2008, De Rouck et al. 2009).

Failure of implants generally occurred in the early stages following dental implant placement. Some studies involved implants that showed mobility after 2-3 weeks (Lindeboom et al. 2006) while others proved to be more dispersed in regards to time of failure. In 2008, De Rouck and colleagues had one implant fail after one month with concurrent pain, mobility and discomfort. Likewise, in 2009, De Rouck, et al. had one implant lost due to mobility after the first month, one lost due to mobility after three months, and one was lost with concurrent pain after three months. In all immediately placed implants, failures occurred for all restorative treatment groups: delayed restorations, immediately provisionalized and immediately loaded implants. However, all treatment groups demonstrated good-excellent success rates of 92%, 88-97% and 92% respectively. (Lindeboom et al. 2006; De Rouck et al. 2008; De Rouck et al. 2009).

**Complications**

The majority of the included studies experienced complications. Complications were defined as any event that required clinical chairside time after delivery of the prosthesis (Lang et al. 2004). Two of the studies included in this review did not account for any complications (Oh et al. 2006; Hall et al. 2007).

Some of the complications reported were biologic while others were technical and associated with the restorative crown. Observed biological
Complications include fistulas (Gotfredsen et al. 2004; De Rouck et al. 2008), soft tissue dehiscence (Gotfredsen et al. 2004), peri-implant mucositis, (Chen et al. 2007) and abscess formation (Chen et al. 2007). Gotfredsen and colleagues (2004) reported that there was a gap at the implant abutment interface in the case that had a fistula. All biologic complications did not result in implant removal and were treated with local debridement and antibiotics.

Technical complications include loosened abutment screws (Gotfredsen et al. 2004; Lindeboom et al. 2006), porcelain fractures (Gotfredsen et al. 2004; Lindeboom et al. 2006) and loss of crown retention (De Rouck et al. 2008). Loose screws were tightened and occasionally accessed through cemented crowns. The technical complications were managed on a case by base basis, with regards to fractured porcelain. The porcelain fractures were resolved through crowns replacement or smoothing with polishing burs. The broad array of complications throughout the selected articles lacked association with implant placement strategies or restorative protocol.

Radiographic evaluation

Many of the selected studies utilized radiographic evaluation as a tool in comparing different surgical and restorative protocols. However, every study that used radiographic evaluation observed a mere lack of correlation between the factors of interest. For example, it was determined that radiographic measurements of implant positioning to approximate tooth demonstrated poor correlation with papilla index (Hall et al. 2007).
In addition, mean bone loss did not differ significantly between immediately loaded and immediately provisionalized groups (Lindeboom et al. 2006). This group reported that the mesial marginal bone loss over a 12-month evaluation was minimal being 0.27(SD=0.2) mm for the immediate load group versus 0.28(SD=0.22) mm for the immediate placement group. Likewise, the distal marginal bone loss over 12 months was 0.19(SD=0.15) mm for the immediate load group versus 0.2(SD=0.11) mm for the immediate placement group.

Chen and colleagues (2007) reported that mean radiographic crestal bone levels around immediately placed tissue level implants were not statistically different between subjects that received no grafting versus grafting (BioOss® with resorbable collagen membrane). Their results did indicate that the most change (0.2(SD=0.8) mm) occurred from time of placement to surgical re-entry, 6 months following. Radiographic analysis from a study by De Rouck and colleagues (2008) also demonstrate the largest amount of bony changes in the first few months following implant placement. At 3 months, they reported mean loss of 0.58 mm mesially and 0.47 mm distally with diminished loss thereafter. After 1 year of function, mean bone loss was 0.98mm and 0.78 mm for mesial and distal aspects of the fixture. The same group conducted a trial comparing immediate restorations versus delayed restorations (De Rouck et al. 2009) and found that radiographic measures of bone levels did not differ significantly between the two groups at the 12-month follow up. Cumulatively, radiographic analysis further demonstrates the multidimensional nature and lack of correlation of factors in relation to the overall esthetic success.
Patient satisfaction

Of the 12 included studies, only four incorporated a self-report to reflect patient satisfaction. Each of these four studies utilized a 10 cm Visual Analog Scale (VAS) to reflect the degree of patient satisfaction, and high scores were readily apparent in all cases. One study determined that there lacked correlation between the clinicians’ objective means of scoring the implant restoration (Implant Crown Aesthetic Index) and the patients’ satisfaction (Meijndert et al, 2007). Interestingly, the Implant crown Aesthetic Index yielded acceptable result for 66% of the cases while the patient satisfaction questionnaire revealed an acceptable result for 100% of the cases. There was a correlation between the patients’ and professionals’ opinion of the peri-implant mucosa, however.

Another study reported VAS scores for both function and esthetic appearance of the implants. In both categories, patient and dentist VAS scores failed to correspond as patients scored themselves higher than the dentist (Gotfredsen et al. 2004). De Rouck and colleagues (2008) demonstrated mean patient VAS score of 93% with a range from 82-100%, but did not compare these scores to objective measures. The same group also investigated VAS for patients that had immediate restorations versus delayed restorations and found similar esthetic satisfaction of 93% and 91% respectively. Moreover, in two of the studies, a higher degree of patient satisfaction was apparent for earlier restoration groups in comparison with delayed restoration groups (De Rouck, 2009; Gotfredsen, 2004).
Peri-implant Structures

Six of the chosen studies measured papilla fill or utilized a papilla index to reflect the changes in interproximal tissue volume during the duration of the study. Gotfredsen and colleagues (2004) reported that papilla shrinkage was not significant during their 5-year evaluation for both early and delayed placement groups. Overall, they found an increased in papillary fill over time. Oh and colleagues (2006) performed a flapless approach on all subjects and demonstrated an increase in papilla index from baseline to 6 months, however it was only statistically significant for the immediate load group and not the delayed load group. Furthermore, there were not any significant differences between treatment groups at each time point.

Other authors also found minimal differences between the papilla index of test and control groups. In a study comparing immediate load versus immediately provisionalized implants, investigators found that full regeneration of the mesial interdental papilla was observed in 70% of the immediate load group while 91% was observed in the immediate provisional group (Lindeboom et al. 2006). Both groups had 91% complete papilla fill on the distal. Furthermore, they did not demonstrate statistical differences in the midbuccal aspect of the tissue, which were reported to be similar to adjacent teeth 91-100% of the time. The group concluded that their results demonstrate no differences in gingival esthetics in both study groups.

At 1 year, Hall and colleagues (2007) compared conventional two-stage approach to an immediate provisionalization group and found that the papillary
index was not statistically different. Furthermore, the papilla index was poorly correlated to radiographic measurements of the implant position to the adjacent tooth. The largest amount of papilla loss was found at the 3 month assessment in both immediately restored and delayed restoration groups (DeRouck et al. 2008). Mean papilla shrinkage was demonstrated to be twice as high for the delayed restoration group when compared to the immediate restoration group. They also reported significant papilla regeneration in the delayed restoration group at 1 year.

Finally, De Rouck and colleagues (2009) found that the largest reduction in papilla height was found at the 3-month follow up visit for implants that were immediately placed and provisionalized. They also demonstrated a trend of recovery in papilla height following 3 months of healing, although this was not statistically significant. Overall, the selected articles for this review demonstrate that there is not a difference in papilla fill when various surgical and prosthetic protocols are utilized and the most change occurs in the first 3 months following implant placement.

**Peri-implant Health**

In addition to papilla index, a variety of other tests were employed to assess the peri-implant tissues. These factors include probing depth, gingival margin, bleeding on probing, and tissue color. Four of the selected articles incorporated measurements of probing depth. In this group of studies, probing depth scores revealed no significance when comparing groups of interest (Oh et al. 2006; Chen et al. 2007; De Rouck et al. 2009; Hall et al. 2007).
Lindeboom et al. (2006) incorporated the gingival margin level in their clinical analysis and concluded that 100% of the implants in the immediately loaded and 91% of the implants in the immediately provisionalized (non-loaded) group had an ideal buccal margin.

Bleeding on probing (BOP) was recorded in a few of the studies as an indication of peri-implant health. Two studies determined there to be no difference between immediately loaded and delayed groups (Oh et al. 2006, De Rouck et al. 2009). In addition, it was determined that BOP scores consistently decline with time. In 2008, De Rouck et al. found that BOP scores were 54% at 1 month and 41% at 1 year with an immediately placement and provisional protocol. Additionally, Gotfredson et al. (2004) found that at the 3-year follow-up 54% had a bleeding score of 0 while at the 5-year follow-up 62% had a bleeding score of 0.

**Esthetics**

The majority of the chosen articles did not incorporate the esthetic outcome in their analysis. In fact, only five analyzed factors that contribute to the overall esthetic outcome. Four of these studies utilized the VAS that was previously discussed (Meijndert et al. 2007; De Rouck et al. 2009; De Rouck et al. 2008; Gotfredsen et al. 2004). Gotfredsen and colleagues (2004) were unique in their use of the VAS in that they incorporated an independent dentist for unbiased assistance in ranking esthetics.

Current literature review indicates that the use of an objective measurement tool for esthetic outcome is not pronounced. Meijndert et al. 2007 was the only
study that utilized an objective measurement index (Implant Crown Aesthetic Index). They reported an acceptable result in 66% of the cases, however, this did not correlate with the patients' self-evaluation using VAS.

**Bony architecture**

As previously discussed, the vast majority of the chosen articles measured marginal bone level changes in their analysis. No trend can be drawn in terms of whether mesial or distal bone loss was more common, as it varied with each study. However, as a general trend, the largest amount of bone loss was observed in the first 3 months. After this initial period, the amount of bone loss notably declined (De Rouck et al. 2008; De Rouck et al. 2009, Chen et al. 2007). For example, De Rouck and colleagues (2008) found that marginal bone loss in the first 3 months was 0.58 mm mesially and 0.47 mm distally. After the span of one year, levels of marginal bone loss were recorded to be 0.98 mm mesially and 0.78 mm distally.

In addition, bone level changes between experimental and control groups proved to be relatively consistent. In three studies (De Rouck et al. 2009; Lindeboom et al. 2006; Hall et al. 2007) it was determined that after 1 year, there was not a long-term difference between bone loss in immediately loaded versus comparison group (delayed, non-loaded provisionalized, or conventional). One study concluded that dimensional changes were not significant between cylindrical or tapered implant configurations (Sanz et al. 2010).

A group of studies concluded that the thickness of buccal bone, implant positioning, and the dimension of horizontal gap all had a direct impact on hard tissue alterations that occur following implant placement. Authors report that their
outcomes were consistently dependent on the baseline characteristics. Three studies conducted by this group agree that sites with thick boney walls corresponded to a greater degree of bone fill. Furthermore, sites with a thick buccal bone crest experienced smaller degrees of vertical resorption (Huynh-Ba et al. 2010; Ferrus et al. 2010; Tomasi et al. 2010). Implants that were more apically positioned experienced less thread exposure than implants that were positioned closer to the alveolar crest, suggesting that anterior sites are more susceptible to ridge alterations (Ferrus et al. 2010; Tomasi et al. 2010). Finally, there is a negative correlation between the size of the vertical residual gap and the vertical position of the bone crest opposite the implant. A positive correlation exists between size of the horizontal gap, the horizontal residual distance, and the residual depth. Essentially, the larger the horizontal gap (>1mm), the greater the amount of newly formed bone. (Ferrus et al. 2010; Tomasi et al. 2010; Huynh-Ba et al. 2010; Sanz et al. 2010).

Finally, one study concludes that since a buccal bony wall width of 2 mm is not found in most extraction sites in the maxilla, most clinical situations may need augmentation procedures to achieve adequate bony contours around the implant. This underscores the importance of the peri-implant hard tissue and their role in supporting the soft tissues that are crucial to maximum esthetic success.
<table>
<thead>
<tr>
<th>Test</th>
<th>Design</th>
<th>No. of Patients/Survival/Complications</th>
<th>Survival/Success</th>
<th>Complications</th>
<th>PES</th>
<th>Papilla index</th>
<th>Tissue color</th>
<th>BOP</th>
<th>Self Report</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chen et al. 2007</strong></td>
<td>RCT</td>
<td>10/10/10</td>
<td>Y</td>
<td>Y- abscess</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Marginal defect fill, bone loss, residual defect, mucosal change, PD</td>
</tr>
<tr>
<td><strong>De Rouck et al. 2009</strong></td>
<td>RCT</td>
<td>24/25</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Marginal bone level changes, PI, PD, midfacial mucosa level</td>
</tr>
<tr>
<td><strong>De Rouck et al. 2008</strong></td>
<td>CT</td>
<td>30</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Radiographic eval, midfacial &amp; papilla soft tissue changes</td>
</tr>
<tr>
<td><strong>Ferrus et al. 2010</strong></td>
<td>CT</td>
<td>93</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Thickness of buccal bone walls, dimensions of the horizontal buccal gap</td>
</tr>
<tr>
<td><strong>Gotfredsen. 2004</strong></td>
<td>CT</td>
<td>10/10</td>
<td>Y</td>
<td>Y-implant &amp; crown</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Visual analog scale</td>
</tr>
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<td>RCT</td>
<td>28/28</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Radiographic eval, peri-implant mucosal response (PD, PI, GI, KT)</td>
</tr>
<tr>
<td>Test</td>
<td>Design</td>
<td>No. of Patients/ implant</td>
<td>Survival/Succes s (Y/N)</td>
<td>Complications (Y/N)</td>
<td>PES (Y/N)</td>
<td>Papilla index (Y/N)</td>
<td>Tissue color (Y/N)</td>
<td>BOP (Y/N)</td>
<td>Self Report (Y/N)</td>
<td>other</td>
</tr>
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<td>------------------------------</td>
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<td>--------------------------------------------</td>
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<tr>
<td>Huynh-Ba et al. 2010</td>
<td>CT</td>
<td>93</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Buccal and palatal bony wall width</td>
</tr>
<tr>
<td>Lindeboom et al. 2006</td>
<td>RCT</td>
<td>50/50</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Jement papilla index, radiographic analysis, midbuccal gingival level</td>
</tr>
<tr>
<td>Meijndert et al. 2007</td>
<td>RCT</td>
<td>31/31/31</td>
<td>Y</td>
<td>Y-Implant</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Implant Crown Aesthetic Index</td>
</tr>
<tr>
<td>Oh et al. 2006</td>
<td>RCT</td>
<td>12/12</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Marginal Level, PD, PI, KT</td>
</tr>
<tr>
<td>Sanz et al. 2010</td>
<td>RCT</td>
<td>93</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Measurements of dimension of the ridge &amp; the void b/t implant &amp; ext socket</td>
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<tr>
<td>Tomasi et al. 2010</td>
<td>RCT</td>
<td>93</td>
<td>N</td>
<td>N</td>
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<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Buccal and palatal bony wall width</td>
</tr>
</tbody>
</table>
Discussion

This comprehensive review assessed implant supported single tooth replacements and esthetic outcomes. There were a variety of parameters that the randomized control trials and clinical control trials identified as variables to evaluate their treatment modalities. We were able to identify outcome measures from the selected studies to include survival, complications, radiographic evaluation of crestal bone changes, patient satisfaction, peri-implant structures, peri-implant tissue health, esthetics, and bony architecture. This review included immediate placement and immediate provisionalization protocols, in addition to conventional approaches. Although there is still insufficient long-term data regarding dental implants in the esthetic zone and esthetics, there are promising trends in the outcomes thus far. Currently, the available controlled clinical trials suggest that immediate and early placement protocols fair just as well as the conventional approach as treatment options. This is particularly important in that immediate restoration of a tooth in the esthetic zone may have profound effects for the patients’ self esteem and satisfaction with treatment.

Overall, dental implants placed in the esthetic zone with various surgical and prosthetic protocols have good-excellent survival rates. The consensus drawn from other reports on single implants with various treatment protocols have demonstrated similar survival rates ranging from 93-100%. Furthermore, The clinical trials examining immediate placement, immediate load single implants demonstrate
positive results. However, authors have mentioned that careful evaluation of the clinical scenario is necessary. Proper diagnostics and treatment planning with an understanding of the peri-implant architecture is key in optimizing results. The studies found that implant loss mostly occurred within the first year of placement and early failures have been reported to be due to lack of primary stability and surgical factors.

The most consistent finding throughout the studies evaluated was that in both soft and hard tissue, the most changes were reported to occur at the 3-month follow up. This can be most readily explained by the fact that tissue remodeling occurs mostly within the first 6-8 weeks following treatment. The studies also indicated that following this 3-month mark, the changes in bone and soft tissue were not only much less in magnitude but also not statistically significant.

Importantly, objective outcome measures were not used frequently in the selected studies. There have been a few esthetic indices and scores proposed with variable reliability. The one used in the cohort of studies discussed in this review was the Implant Crown Aesthetic Index (Meijer et al. 2005). This index scores a variety of factors including soft tissue form and the contours of the restorative crown. Furhauser et al. in 2005 described the Pink Esthetic Score (PES), which demonstrated better inter-examiner reliability and intra-examiner reproducibility. It is also beneficial in that it focuses on soft tissue factors; it is also composed of various soft tissue factors that can be assessed independently. Belser et al. 2009 described the White Esthetic Score (WES)
to be used in conjunction with PES so that the both soft tissue factors and the restorative crown can be scored independently, and ultimately combined to assess overall esthetic outcome. Since these indices are relatively new, there are not many studies that have utilized them to evaluate esthetics. However, it is important to be able to objectively measure esthetic outcomes as we can compare esthetic scores with patient based outcomes such as VAS or OHIP scores. Although the patients’ opinion may depend highly on personal expectations and on baseline esthetics, being able to identify the threshold for patient satisfaction is key in becoming clinically efficient.

Further studies concerning patient specific factors, including health status and tobacco/alcohol use, are imperative for our continued understanding of dental implant therapy. From the studies included in this discussion, Tomasi and colleagues (2010) found through multilevel modeling that other factors, including age and smoking, were important in successful vertical gap fill in immediately placed implants. Age has been associated with decreased vascularization and bone formation in animal models (Lu et al. 2008). Furthermore, smoking has been described as a risk factor in dental implant placement. Through retrospective studies, smokers have been found to be at an increased risk of complications, have peri-implant mucositis, peri-implantitis and implants lost (Bain and Moy 1993; Rodriguez-Argueta et al. 2011; Cavalcanti et al. 2011).

The literature included in this review suggests that implant esthetic success is multi-factorial. Importantly, the baseline soft and hard tissue architecture is an
essential for the esthetic success of dental implants in the esthetic zone. Although there is a lack of well-designed controlled clinical trials that infer certain interventions produce better treatment outcomes, clinicians may improve esthetic success with adequate architectural assessment followed by choosing the appropriate surgical procedures and implant components that may enhance results.
References


