ESTHETIC CRITERIA ANALYSIS OF SINGLE-TOOTH IMPLANT-SUPPORTED RESTORATIONS IN THE ANTERIOR MAXILLA

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ABSTRACT

**Background:** Although criteria concerning the functional assessment of implants are prevalently employed for the determination of implant success, the evolution of esthetic indices for objective evaluation of soft-tissue esthetics and the final prosthesis can be useful for determining overall success. As patient demands for esthetic implant restorations increase, treatment planning with a clear view of esthetic outcomes is imperative to achieve overall success for our implant patients.

**Objective:** To compare implant restorations using Albrektsson’s implant success criteria and a global esthetic assessment consensus by an expert panel. Individual implant and/or implant restoration characteristics that are preferentially correlated with esthetic success were examined and esthetic criteria recommendations were developed based on data points obtained in this study.

**Materials and Methods:** Patients who received single-tooth implant fixture placement #6-11 at the University of Alabama at Birmingham School of Dentistry and who had final restorations in function for > 1 year were identified using a search of the computerized database. Periodontal charting as well as radiographic, photographic, and study cast analyses were implemented in this study for data collection.

**Results:** After statistical analysis was performed, approximately 75% (32 out of the 43 implants) were deemed to be an esthetic failure by 3 or more examiners on the expert panel. Of the 6.98% (3 of the 43 implants) of the implants that failed to meet
Albrektsson’s criteria for implant success, all were judged to be esthetically unsuccessful by 3 or more examiners on the expert panel.

**Conclusions:** 1) The association between function and esthetic was not statistically significant in this investigation; 2) There appears to be no association between single-tooth implant-supported restorations in the anterior maxilla that meet Albrektsson’s implant success criteria and those restorations that meet esthetic success standards as determined by a global esthetic assessment; 3) Implant restorations that fulfill functional success parameters do not necessarily translate into the achievement of esthetic success; 4) Further studies are needed in order to amend existing success criteria commonly used for implant success standards.

Keywords: dental implants, esthetic success, functional success, esthetic criteria
DEDICATION

I would like to dedicate this thesis to my family and closest friends who stood by me and supported me throughout this endeavor.
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CHAPTER 1
INTRODUCTION

With the advancements that have occurred in implant design to improve osseointegration and functional success, esthetics has become a critical goal for both patients and practitioners in implant dentistry. When dental implants were first introduced, the importance of implant esthetics was discounted in favor of concepts such as function, structure, and biology.\(^1\) The most widely used implant success criteria, proposed by Albrektsson and colleagues in 1986, focuses on clinical and radiographic measures of functional implant success, such as the presence of mobility, periapical radiolucency, crestal bone loss, patient reported discomfort, and/or the presence of pathology/disease.\(^2\) However, as patient demands for esthetic implant restorations increase, treatment planning with a clear view of esthetic outcomes is imperative to achieve overall success for our implant patients.

*Implant Success*

The application of dental implants for single-tooth replacements has evolved into a viable prosthodontic alternative to conventional fixed bridgework, resin bonded restorations or removable partial dentures.\(^3\) Most studies use current success criteria for
the evaluation of dental implants.\textsuperscript{2,4,5} Most commonly, Albrektsson’s success criteria are used to define implant success. This definition includes the following factors: 1) absence of persistent signs/symptoms such as pain, infection, neuropathies, parathesias, and violation of vital structures; 2) implant immobility; 3) no continuous peri-implant radiolucency; 4) negligible progressive bone loss (less than 0.2mm annually) after physiologic remodeling during the first year of function; and 5) patient/dentist satisfaction with the implant-supported restoration.\textsuperscript{2,4,5} In general, multi-year studies of implants in partially edentulous patients have commonly reported greater than 90% success rates for both maxillary and mandibular implants.\textsuperscript{6-12} With regard to single-tooth restorations on dental implants, literature studies have shown excellent survival rates, varying from 96.1\% to 98.9\% after 7.5 years in function (Creugers et al. 2000).\textsuperscript{13} Numerous studies\textsuperscript{14-18} have also reported similar implant survival and success rates for implants inserted in the esthetic zone compared to those placed in other segments of the jaws.\textsuperscript{19} With the predictability of osseointegration and long-term success of implant fixtures using different types of restorations and in various locations, the focus of implant dentistry has shifted from survival of the implant/restorations and improvement in function, to more esthetic concerns.\textsuperscript{20}

\textit{General Treatment Planning Concepts in the Anterior Maxilla}

Esthetics is often a prime goal of the clinician and patient when replacing missing teeth in the anterior maxilla. The anterior maxillary teeth in the “esthetic zone” usually extend from first premolar to first premolar, but in some individuals can extend as far
distally as the first molar dependent upon individual patient factors. Articles focusing on gingival esthetics have, in general, limited their investigations to the six maxillary anterior teeth spanning from canine to canine. A challenge in assessing esthetics for such investigations is the reality that the judgment of esthetics is subjective and that esthetic norms vary between cultures and groups. This makes an absolute evaluation of esthetics difficult to perform in a scientific way. An understanding of the patient’s needs and desires as well as a correct balance between demands is important to establish at the beginning of treatment planning and discussion toward the potential end result.

To be a viable treatment alternative for tooth replacement in the esthetic zone, implant-supported restorations should be judged equally or more esthetic than traditional crown and bridge restorations. Previous research indicates that the condition of the peri-implant soft tissues is a critical determinant of esthetic success, particularly in the anterior esthetic zone. Therefore, success of single-implant therapy in the anterior maxilla is not only determined by high survival rates, but also influenced by the esthetic perceptions of the patient and by the quality and stability of the peri-implant tissues. An ideal prosthesis should fully recapitulate or enhance the esthetic features of the tooth or teeth it replaces. Preferably, the appearance of the peri-implant soft tissue should be in harmony with the mucosa around the adjacent teeth and the implant crown should be in balance with the neighboring dentition (Meijer et al. 2005).

The ability to achieve an indistinguishable restoration is a primary goal in the replacement of any tooth, particularly in the maxillary anterior region. Achieving this
objective requires a restoration that mimics its natural counterpart in shape, contour, texture, and color as well as gingival tissues that allow for a natural color, contour, and emergence profile.\textsuperscript{30} One problem often encountered is that dental implants themselves do not mimic the radicular cross-sections of teeth and are not oriented in the alveolar bone in the same way.\textsuperscript{30} Therefore, to create an illusion of normal form, a significant change in gingival contours must be developed by a restoration that reproduces the appearance of a natural tooth on a foundation that rarely mimics the shape or location of the natural roots.\textsuperscript{30} Ultimately, the management of the associated gingival tissues may dictate the final esthetic outcome and a compromise in esthetics may be likely when this consideration becomes subservient to the other treatment planning factors.\textsuperscript{30}

\textit{Prerequisites for Implant Therapy}

Patient screening is one of the fundamental steps in the treatment planning sequence and correlates to the success of implant therapy. It is essential that a candidate for implants be evaluated for potential contraindications to their placement.\textsuperscript{4} At present, there are no reports of absolute medical contraindications for placement of implants, but relative contraindications do exist.\textsuperscript{31} Adverse effects on implant survival have been attributed to uncontrolled diabetes, alcoholism, heavy smoking, post-irradiated jaws, and poor oral hygiene.\textsuperscript{32-35} However, individuals with a strong susceptibility to periodontitis may be treated successfully with implants.\textsuperscript{36}
Restorative requirements, interarch space and jaw relationships, location of edentulous areas, and the quantity and quality of available bone should be evaluated before implants are selected as a treatment option. Radiographs, including panoramic, lateral, and occlusal views and periapical films, may be necessary to determine the height of available bone and for selection of the dimensions of the implants. They also may be needed to determine the proximity of potentially complicating structures including the maxillary sinuses, foramina, mandibular canal, and adjacent teeth or roots. The use of 3-dimensional computerized tomography (CT) scans might be advocated when more accurate information regarding the topography of osseous structures is required.

*General Diagnostic Smile Analysis for the Anterior Maxilla*

When beginning with esthetics, the treatment planning process must begin with an appraisal of the position of the maxillary central incisors relative to the upper lip. In the average smile, the lip is positioned to show 75 to 100 percent of the maxillary central incisor and the interproximal gingiva. A high smile line reveals the total cervical-incisal length of the maxillary anterior teeth and a contiguous band of gingiva. A low smile line displays less than 75 percent of the anterior teeth. Previous studies have shown that with advancing age, the amount of incisal display decreases proportionally. For example, in a 30-year-old, 3 millimeters of incisal display at rest is appropriate. However, in a 60-year-old, the incisal display could be 1 mm or less. The change in incisal display with time probably relates to the resiliency and tone of the upper lip, which tends to decrease with advancing age.
Midline deviation and mal-alignment of the maxillary central incisors should be evaluated during the diagnostic evaluation of the patient. If the midline is deviated to the right or left, studies have shown that midline deviations of up to 3 or 4 mm are not noticed by laypeople as long as the long axes of the teeth are parallel with the long axis of the face.\textsuperscript{43,44} Taking this into consideration, the more important relationship to evaluate may be the medio-lateral inclination of the maxillary central incisors. Researchers have found that if the incisors are inclined by 2 mm to the right or left, laypeople regard this discrepancy as unesthetic.\textsuperscript{44,45} Correction of deviations and/or malalignments may be necessary prior to implant placement to ensure an optimal esthetic outcome.

Once the correct incisal edge position and midline relationship of the maxillary incisors have been established, the next step is to evaluate the labio-lingual inclination of the maxillary anterior teeth. Generally, the labial surface of the maxillary central incisors should be perpendicular to the occlusal plane. This relationship permits maximum direct light reflection from the labial surface of the maxillary central incisors, which enhances their esthetic appearance.\textsuperscript{46} If teeth are retroclined or proclined, correction may require either orthodontics or extensive restorative dentistry and, possibly, endodontics to establish a more ideal labio-lingual inclination.\textsuperscript{47} After the position of the maxillary central incisal edges have been determined, the incisal edges of the maxillary lateral incisors and canines, as well as of the buccal cusps of the maxillary premolars and molars, can be established.\textsuperscript{1}
The position of the maxillary lateral incisors is equally significant to appraise in comparison to the maxillary central incisors. The maxillary lateral incisor crown is more slender than the central incisor and may lean more medially. In addition, the labial surface is more convex than the central incisor, which may be a restorative consideration when fabricating the appropriate contours of the final crown. Frequently, the root of the maxillary lateral incisor is bent distally or disto-lingually near the apex, which may impact adjacent implant placement.

The key to determining the correct gingival levels is to determine the desired tooth size relative to the projected incisal edge position. Therefore, the ideal gingival levels are determined by establishing the correct width-to-length ratio of the maxillary anterior teeth, by determining the desired amount of gingival display, and by establishing symmetry between right and left sides of the maxillary dental arch. If the existing gingival levels will produce a tooth that is too short relative to the projected incisal edge position, then the gingival margins must be moved apically. The key factors that determine the most appropriate method of correction include the sulcus depth, the location of the cementoenamel junction relative to the bone level, the amount of existing tooth structure, the root-to-crown ratio and the shape of the root.

The next step in the process of establishing the correct esthetic position of the maxillary anterior teeth is to assess the papilla levels relative to the overall crown length of the maxillary central incisors. Research has shown that the average ratio is about 50
percent contact and 50 percent papilla.\textsuperscript{53} If the contact is significantly shorter than the papilla, it usually indicates moderate-to-significant incisor abrasion, which tends to shorten the crowns and, therefore, shortens the contact between the central incisors.\textsuperscript{54} If the contact is significantly longer than the papilla, it could suggest that the gingival contour or scallop over the central incisors is flat, which could be caused by altered passive or altered active eruption of the teeth.\textsuperscript{55}

\textit{General Surgical Factors}

Three important guidelines have traditionally governed both submerged and non-submerged endosseous dental implant systems.\textsuperscript{4} These are: 1) surgical procedures that minimize thermal trauma to bone; 2) a primary healing period of variable duration to permit osseointegration of the implant fixture; and 3) prevention of micromotion greater than 100\textmu m during the healing period.\textsuperscript{56} However, the necessity of an initial unloaded period of three to six months to achieve osseointegration is an area of evolving research with several reports suggesting that implants can be placed into function at the time of surgery, if they are splinted.\textsuperscript{56-60} The importance of controlling heat generated by surgical implant site preparation has been demonstrated in both animal and human studies.\textsuperscript{61,62} Thermal trauma to bone can be avoided by the use of low speed, high torque handpieces and a graded series of both externally and internally cooled drills.\textsuperscript{63} Surgical procedures may be performed under aseptic conditions, and a retrospective study addressing implants placed under aseptic “clean” conditions as compared with “sterile” or operating
room conditions showed no significant differences in success rates using either technique.\textsuperscript{64}

Bone quality and bone volume influence successful outcomes of implant therapy.\textsuperscript{4} The maxilla has thin porous bone on the labial aspect, very thin porous-to-dense compact bone in the nasal region and thick cortical bone on the palatal aspect.\textsuperscript{39} The trabecular bone often is less dense than the mandible.\textsuperscript{39} Classically, bone quality of edentulous areas of the jaw has been classified as type I through type IV.\textsuperscript{39} Type I bone has homogeneous cortical bone with no cancellous bone, whereas type IV bone has an extremely thin compact layer and cancellous bone of reduced density. Type II carries mostly cortical bone and some cancellous bone, while Type III presents cancellous bone surrounded with a 3- or 4-millimeter–thick layer of compact bone. Researchers have reported predominance of Type III bone in the anterior and premolar regions of the maxilla.\textsuperscript{39}

The volume of available bone for implant placement is another important factor to assess in the surgical evaluation of the patient. The alveolar bone reacts to dental extraction by remodeling its structures, removing bone at its outer surfaces and depositing bone in the empty sockets. The various factors affecting alveolar bone resorption can be classified as mechanical, biological and anatomical. Five general groups of diverse jaw shapes encountered after extraction are as follows: 1) most of the alveolar ridge is present; 2) moderate residual ridge resorption has occurred; 3) advanced residual ridge resorption has occurred and only basal bone remains; 4) some resorption
of the basal bone has occurred; 5) extreme resorption of the basal bone has taken place.\textsuperscript{39}

Depending on the resorption pattern of the bone encountered and the time since extraction, additional procedures may be needed for proper implant placement.

The quality and quantity of bone play a significant role in the success of implant stabilization at the time of surgical insertion and during the early healing stages of osseointegration. Lower success rates are associated with cancellous than with cortical bone.\textsuperscript{65,66} The volume density of bone matrix in cortical bone is about 80 to 90\% and in cancellous bone about 20\% to 25\%.\textsuperscript{67} Therefore, cortical bone contributes to greater implant-bone contact and implant fixation.\textsuperscript{4}

If bone quality and quantity are inadequate for the placement of implants, bone augmentation procedures may be indicated.\textsuperscript{4} These could include the use of either bioabsorbable or non-resorbable barrier membranes and bone grafts, bone substitutes, and/or growth factors to enhance bone regeneration.\textsuperscript{68,69} A review of the literature indicated that implants in grafted bone do not demonstrate decreased success rates compared with those placed in native bone.\textsuperscript{70} However, it was unclear as to which graft materials are most efficacious.\textsuperscript{70} Accordingly, long-term, well-controlled, prospective longitudinal comparative studies are needed in this rapidly advancing area of reconstructive bone surgery.\textsuperscript{71,72}
The main esthetic objectives of implant therapy from a surgical point of view are the achievement of a harmonious gingival margin without abrupt changes in tissue height, maintaining intact papillae, and obtaining or preserving a convex contour of the alveolar crest. In addition, implant therapy in the anterior maxilla is challenging for the clinician because of the esthetic demands of patients and difficult pre-existing anatomy. In this area of the mouth, the clinician is often confronted with tissue deficiencies caused by various anatomic and pathologic conditions. Tissue deficiencies in the esthetic zone require proper pre-treatment planning for both function and esthetics that may not be required elsewhere in the dentition during implant treatment.

An optimal esthetic implant restoration depends upon anatomic and surgical parameters. These factors may include the following: (1) submucosal positioning of the implant shoulder, (2) adequate 3-dimensional implant positioning, (3) long-term stability of esthetic and peri-implant soft tissue contours, and (4) symmetry of clinical crown volumes between the implant site and contralateral teeth. Due to these requirements, implant placement in an optimal position must begin with a restorative plan and an anatomic assessment of the edentulous site present in the anterior maxilla.

Surgical considerations regarding optimal implant positioning play an important role in the final prosthetic outcome. When determining the buccolingual positioning of an implant, two factors play a critical role in clinical decisions: bone thickness with adequate blood supply and the appropriate implant angulation for the proper emergence
profile. An implant should be surrounded with bone at least 1 mm thick on both the
buccal and lingual aspects. When a mean facial bone thickness of 1.8 mm or larger
remains after site preparation, the potential for bone loss decreases significantly and bone
apposition is more likely to occur. An implant should be surrounded with bone at least 1 mm thick on both the
buccal and lingual aspects. When a mean facial bone thickness of 1.8 mm or larger
remains after site preparation, the potential for bone loss decreases significantly and bone
apposition is more likely to occur. In addition, the implant body should be aligned with
adjacent teeth as well as with the dentition in the opposing arch for proper occlusion. If
an implant must be placed palatally, for each millimeter of palatal inclination, the
implant should be placed an additional millimeter apically to correct angulation. If the
buccolingual dimension of the maxillary arch is compromised, guided bone regeneration
(GBR) should be considered to allow implant placement at the appropriate buccal or
lingual position.

The ideal placement of the implant in the apico-incisal or sagittal direction should
be 2 to 3 mm above an imaginary line that connects the anticipated gingival margin of
the adjacent maxillary teeth. This allows for the transition from the narrow circular
cross-section of the implant to that of the natural tooth size at the gingival margin. The
width of the cross-section of the tooth to be replaced determines the depth of placement
in an apico-coronal orientation. Replacement of a mesiodistally narrow tooth would
require placement of the fixture less apical than that of a wider tooth. The depth of
place ment is important, as if the implant is positioned too far apically, it may result in
increased pocket depths around the transmucosal insert or the abutment, hindering proper
hygienic maintenance. On the other hand, the placement of an implant too incisally may
result in a short overcontoured crown that may be esthetically unacceptable.
When determining the mesial-distal positioning of an implant, a minimum of 1.25 mm of clearance is required between the implant fixture and adjacent teeth for proper osseointegration and decreased risk of damage to adjacent natural teeth. When calculating the mesial-distal distance to select the appropriate implant diameter, one also has to consider the space required for the fabrication of contact points between crowns. Thus, a minimum of 1.5 to 2 mm of clearance from the adjacent tooth is recommended to obtain optimum esthetics with appropriate space for prosthetic devices related to various implant designs and also for peri-implant tissue health. Implant width and length should be selected before the surgical procedure. The selection is based on the diameter of the missing tooth, the proximity of the adjacent roots, and available bone volume at the edentulous site.

In central incisors and canines, implants with a regular-neck configuration (shoulder diameter of 4.8 mm) are most often used. The minimal mesiodistal gap size for such a standard-neck implant is 7 mm, whereas 8 to 9 mm is ideal to allow a sufficient distance to adjacent roots. The narrow-neck implant with a shoulder diameter of 3.5 mm is most often used in lateral incisor areas with a minimal gap size of 5.5 mm.

The underlying bone structure plays a key role in the establishment of esthetic soft tissues in the anterior maxilla. Two anatomic structures are important when considering soft tissue esthetics: the bone height of the alveolar crest in the interproximal areas and the height and thickness of the facial bone wall. The interproximal crest height plays a role in the presence or absence of peri-implant papillae. Previous investigations at
natural teeth\textsuperscript{73} demonstrated that a distance of 6 mm or more from the alveolar crest to the contact point reduces the probability of intact papillae. This observation has been confirmed with implant-supported restorations as well.\textsuperscript{73} It has also been shown that the height of peri-implant papillae in single-tooth gaps is independent of the proximal bone level next to the implant but is dependent on the interproximal bone height of the adjacent teeth.\textsuperscript{73}

Having a facial bone wall of sufficient height and thickness is important for long-term stability of harmonious gingival margins around implants and adjacent teeth.\textsuperscript{73} In daily practice, implant patients frequently present with a bone wall that is missing or of insufficient height and/or thickness because of the various causes of tooth loss. Attempts to place implants in sites with facial bone defects in the absence of bone reconstruction will frequently result in soft tissue recession, potentially exposing implant collars and leading to loss of the harmonious gingival margin.\textsuperscript{73}

The emergence profile of a dental implant depends upon both implant body angulation and the existing status of the periodontal tissues. The clinical parameters that have been reported earlier should be considered for an optimal emergence of the implant restoration. In regard to implant angulation, implant bodies should be placed at angles less than 25 degrees bucco-lingually since esthetic needs cannot be fulfilled easily with implants placed with wider angles.\textsuperscript{77,78} It is important to remember that soft-tissue augmentation is not possible without hard-tissue support.\textsuperscript{79} Therefore, a ridge deficiency at the implant site should be within 3 mm of its optimal contour to allow the clinician to
modify the soft tissues suitably. To have ideal localization, implant placement in bone requires placement of the implant platform 3 to 5 mm from the cementoenamel junction of the adjacent tooth.\textsuperscript{80,81} Furthermore, both buccal and lingual bone walls should be at least 1 to 2 mm in thickness.\textsuperscript{39}

To allow for a proper emergence profile and to achieve optimal emergence, maintaining 1 mm of bone thickness labial to the implant is ideal.\textsuperscript{76} Placing the implant further in a palatal direction will result in a ditched restoration with a modified ridge lap design for the final restoration. That design hinders the hygiene and affects the esthetic outcome. On the other hand, placing the implant too far labially may jeopardize the esthetics, forcing fabrication of an overcontoured crown, particularly if the positioning is so severe that it is impossible to correct with an angulated abutment. In some cases in which there is no choice but to place the implant in a palatal direction because of anatomical or clinical limitations, the implant should be placed 1 mm apically for every mm that it is placed palatally, as previously mentioned.\textsuperscript{76}

Up to the mid-1990s, alveolar bone loss at the crest was considered to be a physiological response to healing during the first year after dental implant placement.\textsuperscript{5} This was thought to occur as a result of mechanical stress caused by the implant body at alveolar crest level and was defined as “saucerization.”\textsuperscript{82} Currently, it is accepted that this phenomenon occurs not only owing to mechanical stress created by the implant body at the crest but also owing to lack of a space for biological width\textsuperscript{83} and the existence of the microgap\textsuperscript{84} at the alveolar crest level. Cochran and colleagues\textsuperscript{84} reported that a space
of approximately 3 mm in height is required for peri-implant sulcus formation around
dental implants without alveolar bone loss. Also, soft-tissue changes can occur, which
may impact final soft tissue esthetics; an additional 0.75 mm and 0.9 mm of tissue
recession can occur at six months and one year, respectively, after abutment
connection. 85-87

Favorable peri-implant biotype may minimize the impact of physiologic hard/soft
remodeling. The thin scalloped periodontium found in less than 15% of cases is
characterized by a delicate soft tissue curtain, a scalloped underlying osseous form and
often has dehiscence and fenestrations and a reduced quantity and quality of keratinized
mucosa. 88 Generally, interproximal tissue does not completely fill the space between
adjacent teeth. The tooth form in this type exhibits a contact point towards the incisal
third essentially triangular anatomic crowns and contact areas of teeth that are small
facio-lingually and apico-coronally. Due to extreme taper of the roots the bone
interproximally tends to be thicker. 88 This form of gingiva reacts to insults by receding
facially and interproximally. As recession occurs and the inter-radicular bone resorbs,
the subsequent soft tissue loss compromises the overall esthetic result. 88

Characteristics of the soft tissue biotype will play a prominent role in final
planning for the shoulder position of the implant. A thin biotype with highly scalloped
tissue will require the implant body and shoulder to be placed more palatal to mask any
titanium show through. When implants are placed toward the palate a slightly deeper
placement is required to allow for proper emergence profile. 88
The thick flat periodontal biotype is characterized by a denser more fibrotic soft tissue curtain, a flat thicker underlying osseous form and an increased quantity and quality of attached keratinized gingiva. This tissue often reacts to insults by pocket formation. Flat gingiva is associated with a tooth form that is more bulbous. Contact areas are located more toward the middle third of the tooth; primarily square anatomic crowns and contact areas that are wide facio-lingually and apico-coronally.  

The tooth morphology appears to be correlated with the soft tissue quality. The triangular tooth shape is associated with the scalloped and thin periodontium. The contact area is located in the coronal third of the crown underlining a long and thin papilla. The square anatomic crown shape combines with a thick and flat periodontium. The contact area is located at the middle third supporting a short and wide papilla.

The physiological dentogingival junction of natural teeth includes the length of the epithelial attachment, the length of the connective-tissue attachment and the depth of the sulcus. This also is known as “the biological width.” The mean value of the biological width around a natural tooth is 2.73 mm. The implant-epithelium junction is similar to that in the natural dentition, except that it is shorter and thinner than the tooth-epithelium junction. Because of the absence of a cementum layer around an implant, most connective-tissue fibers in the supracrestal region are oriented in a direction parallel to the implant surface. Furthermore, investigators have observed the presence of an avascular zone, 50 to 100 micrometers wide, of dense circular connective-tissue fibers.
that are in direct contact with the implant body at the supracrestal area. The biological width around implants can have significant influence on the character of soft tissues and depends on a variety of characteristics that include implant design, presence of adjacent teeth and quality of soft tissue.

**Other Treatment Considerations**

Various implant treatment strategies have been proposed for the accomplishment of optimal esthetics. These include approaches to rehabilitate the underlying bone structures by augmentation procedures with autologous bone and/or bone substitutes (Weber et al. 1997, Jensen et al. 2006, Pelo et al. 2007), techniques to manipulate and enhance the architecture of the peri-implant soft tissue (Zetu & Wang 2005, Esposito et al. 2007) and methods for alveolar ridge preservation following tooth extraction (Lekovic et al. 1997, Irinakis & Tabesh 2007). Furthermore, implants and abutments with specific configurations have been introduced to sustain the hard and soft tissues (Wohrle 2003, Morton et al. 2004, Lazzara & Porter 2006, Maeda et al. 2007, Noelken et al. 2007) together with provisionalization techniques to restore the soft tissue contour (Jemt 1999, Al-Harbi & Edgin 2007), and the introduction of ceramic customized abutments and ceramic implant crowns (Canullo 2007, Schneider 2008).
Esthetic Factors

Meeting the goal of providing a single-tooth implant crown that equals or exceeds the esthetic value of the tooth it replaces requires identifying and addressing easily recognized anatomic constraints. Recent literature focuses on some of the following objective criteria for evaluating dental esthetics: gingival health, balance of gingival levels, gingival zenith, interdental closure, interdental contact location, tooth axis, basic features of tooth form, relative tooth dimensions, tooth characterization, surface texture, color, incisal edge configuration, lower lip line, smile symmetry, and midline/occlusal plane orientation. The application of time proven and well-documented objective criteria for dental esthetics to the anterior single-tooth implant scenario can guide planning and assure execution of implant placement, abutment design, and crown formation to achieve the highest and most reproducible esthetic goals of the clinician and patient.

Existing Esthetic Criteria and Associated Studies

Although criteria concerning the functional assessment of implants (stability, radiographic bone loss, prosthetic complications, and peri-implant hygiene) are prevalently employed for the determination of implant success (survival), the evolution of esthetic indices for objective evaluation of soft-tissue esthetics and the final prosthesis can be useful for determining overall success. Measured by the abundance of implant dentistry publications chiefly concerned with osseointegration processes and clinical success rates, until late, few studies were concerned with the esthetic parameters of
implant restorations. In general, there is a lack of objective methods of measurement, utilizing a rating score and carried out by a professional observer, in order to assess esthetic quality. This may be due to the subjective nature of esthetics or that historically implant patients may have had significant esthetic compromise prior to tooth extraction. The esthetic result has rarely been included among success criteria for implant therapy, although there is an increasing tendency to do so in the most recent studies, and especially in those that deal with implant-supported rehabilitation in the maxillary anterior areas.

In order to evaluate and record esthetics, a fundamental distinction may be drawn between subjective and objective methods. One subjective method is for the patient to answer questionnaires in which he or she can express his or her satisfaction and any deficiencies that may exist. However, this subjective assessment is not suitable for evaluating any potential sources of error or scope for improvement in restoration. Objective methods by a professional examiner based on defined criteria are rare in the field of esthetic implant dentistry. An objective rating score, with a division in different items, not only gives insight in the esthetic result of a specific treatment, but also facilitates analysis in order to improve surgical and/or prosthetic treatment. Currently, the few indices available, which aim to objectify the esthetic outcome of single-tooth implant crowns, have shown reproducibility, based on calculations of intra- and interobserver agreement. However, the validity of these indexes have not been investigated and although they may show good face validity, the construct validity in particular needs further research.
To date, the most frequently used index is the Papilla Index of Jemt,\textsuperscript{95} which is often used in combination with other indices or integrated with further measurements.\textsuperscript{94} This index is perhaps the first attempt to apply a scientific feature to the esthetic judgment.\textsuperscript{94} The Papilla index defines five distinct levels to assess the size and volume of interproximal papillae adjacent to single-tooth implants, ranging from the complete absence of papillary tissue (index score 0) to hyperplastic papillae (index score 4) as follows:\textsuperscript{95}

\textbf{The Papilla Index of Jemt:\textsuperscript{95}}:

\begin{itemize}
  \item \textbf{Index score 0} – no papilla is present
  \begin{itemize}
    \item There is no curvature of the soft tissue contour adjacent to the single implant restoration
  \end{itemize}
  \item \textbf{Index score 1} – less than half of the height of the papilla is present
  \begin{itemize}
    \item Slight curvature of the soft tissue contour
  \end{itemize}
  \item \textbf{Index score 2} – at least half of the height of the papilla is present, but not all
  \begin{itemize}
    \item Soft tissue contour fairly harmonious
  \end{itemize}
  \item \textbf{Index score 3} – papilla fills up the entire proximal space
  \begin{itemize}
    \item Papilla is in good harmony with adjacent soft tissue contour
  \end{itemize}
  \item \textbf{Index score 4} – papilla is hyperplastic and covers too much of the restoration/adjacent tooth
  \begin{itemize}
    \item The soft tissue contour is more or less irregular
  \end{itemize}
\end{itemize}

This index was used for the esthetic examination of 25 single-tooth implants, reporting a significant spontaneous regeneration of papillae after a mean follow-up period of 18
months compared to the peri-implant soft tissue conditions present at the time of insertion of the restorations. The investigator concluded that the proposed index was suitable for the scientific assessment of soft tissue contours adjacent to single-tooth implant restorations.

By considering only a single variable, the Papilla index runs the risk of producing misleading results and only a partial judgment. It is not a sensitive tool because it does not consider other possible esthetic defects, such as the level of the marginal buccal tissues, the surface color and appearance, the convexity of the alveolar process, and the matching of the implant-supported element with the adjoining teeth and its symmetry compared with the homologous contralateral tooth. The index thus lacks specificity, possibly leading to an unsatisfactory esthetic judgment.

Another system that considers just the interproximal papilla is that proposed by Nordland and Tarnow. The function of this index is to estimate the appearance of the natural teeth; it enables a description of the degree of filling of the interproximal space by the interdental papilla based on three anatomical landmarks: the interdental contact point, the facial apical extent of the cemento-enamel junction (CEJ), and the interproximal coronal extent of the CEJ. Nordland and Tarnow’s system is not appropriate for implant-supported prosthetic elements, as all three of the anatomical points that are considered can undergo changes and may no longer be precise reference points.
It has been proposed that the Jemt’s index is more suitable for the esthetic evaluation of implant rehabilitations with regard to the presence and the height of the interproximal papilla. Nevertheless, both of these indices consider only the interproximal papilla while disregarding the surrounding peri-implant soft tissues characteristics. An accurate and reliable method of esthetic analysis should be sensitive to, and specific for, other esthetic defects based on the evaluation of more variables, each of which could be assessed objectively and quantified.

Subjective methods were also employed in past studies, either utilizing patient questionnaires or a visual analog scale to measure satisfaction and esthetic success. Chang and colleagues reexamined, at least 6 months after the prosthetic restoration, 20 patients treated with an implant-supported single crown in the anterior maxilla. The authors compared the prosthetic element with the restored contralateral tooth and considered numerous parameters concerning the form of the crown, its relationships with the adjacent elements, and the dimensions of the soft tissues. The subjective evaluation of the patients was found to be more positive (mean value of 96% on the VAS) than that of the professionals and the index had a repeatability of 90% at the second observation, which was carried out 1 month after the first.

Slightly different is the Pink Esthetic Score, which takes into account many soft tissue components and has been used by Fürhauser and colleagues to analyze the esthetics of 30 implant-supported single crowns in the anterior maxilla. This pink esthetic score (PES) evaluates the esthetic outcome of soft tissue around implant-
supported single crowns in the anterior zone by awarding seven points for the mesial and distal papilla, soft-tissue level, soft-tissue contour, soft-tissue color, soft-tissue texture, and alveolar process deficiency. With the exception of papilla formation, the evaluation is performed by visually comparing reference teeth. This index not only considers the height of the interproximal papilla, comparable to the Papilla index of Jemt, but also considers other various soft tissue and hard tissue characteristics not previously examined in past studies. Although the index produced highly reproducible results, it was not possible to completely eliminate the influence of the individual, and, in particular, that of the observer’s technical and cultural background.

Even more complex and articulated is the “Implant Crown Aesthetic Index” introduced by Meijer and colleagues, which takes into account some of the features of the crown, such as diameter, position of the incisal edge, labial convexity, color, translucency, and surface characteristics, as well as some soft tissue features, such as labial margin position, interdental embrasure filling, labial mucosa contour, color, and surface. The reliability of this index has been tested by examining the degree of intraobserver and interobserver agreement among four professionals (two maxillofacial surgeons and two prosthodontists) who were asked to evaluate the esthetic result of 24 implant-supported single crowns in the anterior maxilla, with the aid of photographs. The prosthodontists were found to be more reliable and objective observers in comparison with the surgeons because they showed greater interobserver (between the first and second evaluations) and intraobserver agreement.
Meijer and colleagues\textsuperscript{13} showed the Implant Crown Aesthetic Index to have a considerable degree of reliability and suggested that it could be used as a guide to determine a professional’s ability to make coherent judgments.\textsuperscript{94} However, it should be noted that with such a structured evaluation, a large discrepancy from the ideal situation for only one particular variable can bring about a negative judgment of “nonsatisfactory esthetics,” even when there is a positive judgment as regards the other variables, while small discrepancies, which may add penalty points to the final total, allow the attainment of a satisfactory to moderate esthetic judgment.\textsuperscript{94} This may explain why Meijndert et al. (2007), using the Implant Crown Aesthetic Index developed my Meijer, reported that in 34\% of the cases, the esthetics were not acceptable, which is a rather high percentage.\textsuperscript{27}

Juodzbalys and Wang\textsuperscript{98} developed a complex esthetic index (CEI) for rating the esthetics of anterior maxillary implant-supported restorations with respect to the surrounding soft and hard tissues. Fifty patients (31 males and 19 females; age: 18 to 50 years; mean age – SD: 32.4 – 9.1 years) previously treated with dental implants were evaluated regarding the esthetic results of their restorations using the proposed CEI. Two calibrated oral surgeons did the evaluation and recording. The evaluation was carried out twice by each of the examiners 2 weeks apart.\textsuperscript{98}

The proposed complex esthetic index is composed of three components: the soft tissue index (S), predictive index (P), and implant-supported restoration index (R). Within each category, specific parameters were evaluated and graded as adequate (rating 20\%), compromised (rating 10\%), or deficient (rating 0\%). Soft tissue characteristics of
the S that were previously published include soft tissue contour variations, soft tissue vertical deficiency, soft tissue color and texture variations, and mesial and distal papillae appearance. The P primary assessed the following components: mesial and distal interproximal bone height, gingival tissue biotype, apico-coronal position of the implants, and horizontal contour deficiency. The R evaluated the color and translucency of the implant-supported restoration, labial convexity in the abutment/implant junction, implant/crown incisal edge position, crown width/length ratio, and surface roughness and ridges of the implant-supported restoration in relationship to adjacent and contralateral teeth. All mentioned R parameters, with the exception of crown width/length ratio, must be in harmony with the adjacent and contralateral teeth.

Accordingly, when the S, P, and R general ratings were adequate, the CEI rating was 100%. When one of the indices registered between 60% and 90%, this was a compromised and clinically acceptable result. When the CEI was <50%, this was a deficient and clinically unacceptable esthetic outcome. An adequate CEI of S100, P100, and R100 was observed by both examiners in 10% and 12% of cases in evaluations I and II, respectively. Further analysis revealed the importance of each CEI component. It was found that in situations where the CEI was S100, P100, and R <100%, the number of cases was the same as it was using the adequate CEI. When the P was <100%, the number of cases with adequate S and R was reduced more than twice. When the S was <100%, the number of cases with adequate P and R was significantly reduced.
It has become evident from examination of the different methods of evaluating esthetic results presented in the literature that, at present, there is no commonly approved reliable index.\textsuperscript{94} Most authors adopt the Papilla Index of Jemt,\textsuperscript{95} often integrating it with other measurements, or else they propose new methods that are, in their opinion, more complete, objective, and/or reproducible.\textsuperscript{94} Fürhauser and colleagues\textsuperscript{97} and Meijer and colleagues\textsuperscript{13} attempt to objectify their esthetic judgment, creating a system that achieves reproducibility and lacks, as far as possible, the direct influence of the particular characteristics of each observer.\textsuperscript{94}

Nevertheless, the reproducibility of the esthetic judgment is conditioned by some variables proper of the direct observation, of the observation on photographs, and of both the observation method, that must be considered as possible bias.\textsuperscript{94} It appears that the evaluation of photographs, even if it removes some risks specific to direct observation, is inadequate for those variables that require three dimensional observation, such as the degree of labial convexity, or those that may be influenced by brightness, contrast, and neatness of the image, such as the superficial appearance and the color of the soft tissues in comparison with the surrounding mucosa.\textsuperscript{98}

The significance of the esthetic appearance before implant treatment has been identified as a critical factor and might strongly relate to the final esthetic outcome.\textsuperscript{27} To illustrate, when the starting point is favorable, favorable esthetics are more likely after an implant based single-tooth replacement, both from the patients’ and professionals’ perspectives, while an unfavorable starting point might lead to satisfactory results from
the patients’ perspective while the professionals objective judgment might be unfavorable.\textsuperscript{27} This incongruity can easily lead to bias in esthetic implant research.\textsuperscript{27}

In modern implant dentistry, treatment considerations must begin with well-defined esthetic objectives. Identifying realistic esthetic goals and accounting for the impact of the planned treatment on function, structure, and biology, a clinician will be able to deliver the highest level of dental care to each patient\textsuperscript{1}. As our patients become increasingly aware of dental esthetics, establishing a higher standard of care that evolves with the increasing demands of our patients will become a requirement for success.
CHAPTER 2
PURPOSE OF THE STUDY

*Study Goals*

- To compare implant restorations using the following methods: Albrektsson’s implant success criteria; a global assessment for esthetic success as determined by an expert panel

- To determine the rate at which implant restorations which are currently in function and meet Albrektsson’s implant success criteria also achieve esthetic success

- To identify individual implant and/or implant restoration characteristics that are preferentially correlated with esthetic success

- To develop esthetic criteria recommendations using data points obtained in this study
Null Hypotheses

1) Among single-tooth implant restorations that achieve success based upon Albrektsson’s criteria that have been in functional load greater than one year, the rate of achieving esthetic success as judged by global esthetic assessment consensus by a committee of Board Certified Prosthodontists and Periodontists does not differ from the rate of esthetic success among those implant restorations which do not meet Albrektsson’s implant success criteria.

2) There are no differences between single-tooth implant-supported restorations in the anterior maxilla that meet Albrektsson’s implant success criteria and those restorations that meet esthetic success standards as determined by a global esthetic assessment consensus reached by a committee of Board Certified Prosthodontists and Periodontists at measured data points.

Specific Aims

1) Determine if implant esthetic success as determined by a global esthetic assessment consensus reached by a committee of Board Certified Prosthodontists and Periodontists correlates with success or failure as judged by Albrektsson’s implant success criteria.

2) Determine if the following individual implant parameters correlate with implant global esthetic assessment

   a. Papilla Fill
b. Soft Tissue Height Location
c. Presence of Hard/Soft Tissues Deficiencies
d. Gingival Characteristics ie. Color, Texture, & Thickness
e. Presence of Recession
f. Peri-implant Pocket Depths
g. Incisal Edge Location
h. Crown Contour Characteristics

3) Develop esthetic criteria recommendations utilizing those data points that were correlated with global esthetic success.

Objectives

1) Collect data on single-tooth implant-supported restorations in the anterior maxilla through the use of periodontal charting, study models, radiographic and photographic analysis

2) Assess single-tooth implant-supported restorations in the anterior maxilla by determining whether restorations meet esthetic success standards imparted by an expert committee review

3) Evaluate single-tooth implant-supported restorations in the anterior maxilla on the basis of absolute criteria using data points obtained in this study

4) Determine if individual patient identifiers and markers are correlated with overall global esthetic success standards
5) Analyze the data obtained within this study using a chi-square test to examine differences with categorical variables (global assessment = expected outcome, esthetic criteria scoring system assessment, observed outcome).

6) Determine whether a correlation exists between Albrektsson’s criteria for dental implant success and esthetic success as measured by expert global assessment.
A cross sectional investigation of esthetic characteristics of single-tooth implant-supported restorations in place intraorally for at least one year in the anterior maxilla, #6-11, was performed in this study. Implant restorations and fixtures utilized in this investigation were selected retrospectively from those placed in the Graduate Periodontology clinic at the University of Alabama at Birmingham without predilection to any specific implant system. A patient list of potential study participants was obtained from the UAB patient database, which met the following inclusion criteria:

- The existence of one or more non-adjacent, single-tooth, implant-supported crown
- Implant prosthesis in function intraorally for at least one year
- Implants located in the anterior upper jaw, (teeth #6-11)
- Patient age ≥ 19
- Patients are able to give informed consent for themselves
- Patients who can understand written English without the aid of ad hoc interpretation
Patients were eliminated from this investigation as potential study participants regarding the following exclusion criteria:

- Women who report a current pregnancy
- Patients with a previous diagnosis of an “ailing” or “failing” dental implant
- Patients who have received a secondary surgical procedure at the fixture of interest post-implant placement (e.g. guided bone regeneration, soft-tissue grafting)
- Patients who have received replacement of the original restoration at the site of interest.
- Patients with zirconium abutments as part of their implant restorations
- Patients with non-restored missing teeth in the anterior maxilla (teeth #6-11 or canine to canine)
- Patients with notable gingival inflammation (GI = 2/3) in the anterior maxilla as determined by the Löe and Silness Gingival Index
- Patients with non-uniform tooth wear or cervical abrasion at any teeth in the anterior maxilla #6-11
- Patients with evidence of gingival abnormality in the anterior maxillary sextant (#6-11), examples include, but are not limited to: gingival overgrowth, hyperplasia, and exophytic growth/abnormalities

A total of 37 patients, 21 males and 16 females, participated in this study. Verbal and written consent were obtained from each patient prior to the start of the evaluation
process. One sole examiner evaluated single-tooth implants and their corresponding implant-supported restorations via the methods below:

1) Radiographic analysis of radiographs meeting Pritchard diagnostic criteria\textsuperscript{99} to determine success via Albrektsson’s criteria. Pritchard radiographic diagnostic criteria\textsuperscript{99} is listed as follows:

**Criteria of Accuracy of Radiographs:**

- The image of the tips of molar cusps will be recorded with little or none of the occlusal surface showing.
- Open interproximal spaces, proximal contacts do not overlap unless the teeth are actually out of line anatomically.
- Distinct enamel cops and pulp chambers.

**Information That Can be Obtained Only From Radiographs:**

- Root length and morphology.
- Clinical-crown-to-clinical-root ratio.
- Approximate gross amount of bone destruction.
- Most coronal position of bone in the septal regions.
- Condition of the alveolar bone and periodontal space on the mesial, distal, and apical aspects of the root.
- Position of the maxillary sinus in relation to the periodontal deformity.
Information That Cannot be Obtained from Radiographs:

- Existence or absence of periodontal pockets.
- Morphology of bone deformities.
- Soft-to-hard tissue relationship.
- Tooth mobility.
- Position or condition of structures on the buccal, labial, and lingual aspects of the tooth.

2) Periodontal charting documenting periodontal pocket depth (#) via the use of a #15 UNC periodontal probe, BOP (+/-), edema (+/-), erythema (+/-), mobility (+/-), and soft tissue thickness (Y = 1mm or more, as determined by absence of trans-gingival appearance of the periodontal probe, N = less than 1mm, as determined by trans-gingival appearance of the periodontal probe through the gingival tissues)

3) Photographic analysis to determine soft and hard tissue characteristics; 3 pictures were taken at a follow-up time point with the appropriate image ratios as follows:
- 1:1 clinical image of the single-tooth implant-supported restoration
- 1:1 clinical image of the single-tooth implant-supported restoration with a #15 UNC periodontal probe positioned vertically from the soft tissue margin along the long axis of the restoration
- 1:2 clinical image of the retracted frontal profile view of the patient in maximum intercuspation, with maxillary central incisors centered in the image and their incisal edges horizontal to the interpupillary line
4) Study cast analysis to determine the presence of hard/soft tissue deficiencies apical to the implant-supported restoration, and to calibrate measurements taken from the clinical pictures taken in this study. Study casts were taken with full arch stock impression trays and syringable alginate substitute impression material. Impressions were poured up with microstone dental stone and study models were trimmed accordingly so that model bases were parallel to the incisal edges of the maxillary central incisors.

Variables that were assessed in this study include Albrektsson’s implant success criteria, papilla fill/height, soft tissue marginal height discrepancy, hard/soft tissue deficiency of the buccal plate/gingival complex, soft tissue thickness assessment, gingival color/texture deviation, soft tissue profile/contour deformity, gray trans-gingival discoloration from the abutment/implant, recession, bleeding upon probing, periodontal pocket depth, incisal edge discrepancy, crown contour irregularity, and patient satisfaction. Comparison and analysis of quantifiable variables as well as overall esthetics were used to evaluate the objectives of the study and determine the validity of the null hypothesis.
Absolute Criteria

The following data points were collected in each patient case according to the methods outlined below:

1) Albrektsson’s implant success criteria:

   a. Y = meets all of the following criteria:

      i. absence of persistent signs/symptoms such as pain, infection, neuropathies, parathesias, and violation of vital structures, as determined by clinical, radiographic, and patient assessment

      ii. implant immobility, as determined by clinical assessment; the back of two mirror handles were placed on each side (facial and palatal) of the implant restoration and controlled lateral forces not exceeding 10 Ncm were applied; mobility was determined by visual inspection

      iii. no continuous peri-implant radiolucency, as determined by periapical radiographic assessment; the integrity of the surrounding alveolus was scrutinized for fibro-encapsulation, infection, etc.

      iv. negligible progressive bone loss (less than 0.2mm annually) after physiologic remodeling (1mm) during the first year of function, as determined by periapical radiographic assessment; one millimeter of physiologic remodeling was permissible to the first thread of the implant; bone loss beyond that point was measured on the
periapical radiograph using a periodontal probe with millimeter increments; the following calculation was used to determine the amount of crestal bone loss:

1. crestal bone loss (measured as mm/year) = bone loss from the first thread of the implant (measured in mm), divided by the number of years since restoration delivery minus 1

v. patient satisfaction with the implant-supported restoration, as determined by patient assessment; patients were asked if they were satisfied with the quality of esthetics achieved with their implant restorations only and not the overall esthetics in the anterior maxillary region

b. N = fails any one criterion

2) Papilla fill:

a. Y = Complete (75-100% papilla fill present, which is determined in the following manner: using a 1:1 image of the implant restoration in question, a line was drawn connecting the mesial and distal contact points of the implant restoration in question; a parallel line was then drawn tangent to the gingival zenith; papilla fill was then measured in millimeters from the tangent line to the apex of the papilla, divided by the distance from the tangent line to the line connecting the contact points, with conversion into a percentage)

b. N = Incomplete (<75% papilla fill present)
3) Soft tissue height discrepancy:
   a. Y = present, as determined in the following manner: using a 1:2 image, a horizontal line was drawn from the gingival zenith of the implant restoration in question, across to the contralateral reference tooth; the distance from the horizontal line to the gingival zenith of the contralateral reference tooth was then measured in millimeters and scaled using the length of the implant restoration in the 1:2 image, as measured in millimeters, and the exact length of the implant restoration, as measured in millimeters on the study cast model
   b. N = not present

4) Hard/soft tissue discrepancy
   a. Y = present/visible, as determined by visual inspection and palpation of the facial gingival region apical to the implant restoration in question; further verification may have been performed using the study cast models, as needed
   b. N = not present/visible

5) Adequacy of soft tissue thickness:
   a. Y = probe not visible through the gingival tissues (>1mm thickness), as determined by clinical assessment of the implant restoration in question; a periodontal probe was inserted into the mid-facial aspect of the peri-
implant sulcus; visibility of the probe was associated with less than 1mm of gingival thickness, whereas absence of probe visibility was associated with 1mm or more of gingival thickness.

b. \( N \) = probe visible through tissue (<1mm thickness)

6) Gingival color/texture deviation:
   a. \( Y \) = deviation evident, as determined by clinical assessment of the surrounding peri-implant gingival tissues; gingival color and texture around the implant restoration were compared to the adjacent tissue appearance.
   b. \( N \) = no deviation noted

7) Bleeding upon probing:
   a. \( Y \) = Bleeding upon probing (BOP) present, as determined by clinical assessment of the implant restoration in question; immediate as well as delayed bleeding elicited from insertion of a periodontal probe into the peri-implant sulcus were included in this assessment.
   b. \( N \) = BOP absent

8) Periodontal pocket depth:
   a. \( Y \) = PPD > 4mm, as determined by clinical assessment of the implant restoration in question; PPD was measured from the free gingival margin to the base of the peri-implant sulcus; the deepest reading was recorded at
each site, corresponding to the mesial-facial, mid-facial, distal-facial, mesial-palatal, -mid-palatal, and distal-palatal aspects

b. \( N = \text{PPD} \leq 4\text{mm} \)

9) Recession:

a. \( Y = \) present, as determined by clinical assessment of the implant restoration in question; recession was measured as the distance from the implant restoration margin to the free gingival margin; recession with an implant restoration likely corresponded to the appearance of the underlying titanium abutment/implant body seen beyond the gingival margin

b. \( N = \) not present

10) Incisal Edge Discrepancy:

a. \( Y = \) present, as determined in the following manner: using a 1:2 image, a horizontal line was drawn from the incisal edge of the implant restoration in question, across to the contralateral reference tooth; the distance from the horizontal line to the incisal edge of the contralateral reference tooth was then measured in millimeters and scaled using the length of the implant restoration in the 1:2 image, as measured in millimeters, and the exact length of the implant restoration, as measured in millimeters on the study cast model

b. \( N = \) not present
11) Crown contour irregularity:
   a. Y = irregular contour deviation present, as determined by clinical assessment of the implant restoration in question; crown contour irregularity may have included but was not limited to an excessively long or short implant restoration, problematic height of contour, and/or poor emergence profile.
   b. N = irregular contour deviation absent

12) Patient Satisfaction:
   a. Y = satisfied, as determined by patient assessment: patients were asked if they were satisfied with the quality of esthetics achieved with their implant restorations only and not the overall esthetics in the anterior maxillary region
   b. N = not satisfied

Additional information that was collected for future analysis is as follows: crestal bone loss amount after 1 year of physiologic remodeling (1mm), crestal bone loss/year, max periodontal pocket depth, amount of recession, months since restoration placed, implant system used, type of crown: PFM vs. Porcelain, placed in regenerated bone vs. native bone, cement vs. screw-retained crown, months from implant placement to restoration temporization, months since implant placed, mesial papilla height and % fill, distal papilla height and % fill, soft tissue height discrepancy (vs. contralateral tooth),
incisal edge discrepancy (vs. contralateral tooth), crown contour irregularity, crown color irregularity (vs. contralateral tooth), hard/soft tissue deficiency, soft tissue thickness via periodontal probe assessment using a UNC #15 (visible/not visible with probe inserted into sulcus), self-reported smoking status: Y/Former/N (recorded via pack/year history), self-reported diabetic status: Y/N, age (verified via DOB on driver’s license/medical record), sex, implant site #, radiographic distance from implant to adjacent teeth, radiographic distance from contact point to crestal bone height adjacent to implant, radiographic distance from contact point to crestal bone height adjacent to dentition, level of oral hygiene as determined by Silness plaque index at implant of interest, size of the implant (length, diameter), and presence of fremitus (maxillary anterior region).

All data points were compiled and organized on an excel spreadsheet for tracking purposes. Quantification of the absolute criteria data points was performed using binary coding (0 or 1 indicating a Y or N response, according to the data point assessed) in order to summarize the findings of the study. Descriptive analysis in this investigation was acquired from the aforementioned method.

Global assessment of esthetics was carried out by an expert panel consisting of four periodontists and one prosthodontist. A 1:2 clinical image, consisting of a retracted frontal profile view of each patient, was presented to the expert panel for evaluation. Esthetic success was determined via Y/N response based on the expert opinion and individual bias of each member of the panel. In cases where an esthetic success was not achieved, failure was attributed to soft tissue contours, prosthetic contours, or both. All
information was recorded on worksheets used during the evaluation session and compiled on a master spreadsheet for statistical analysis.

Esthetic success and failure were calculated based on whether three or more experts agreed on the rating. Frequencies, percentages and chi-squares were calculated to determine the relationship between soft tissue, prosthetic, and esthetic success and failure. All analysis was performed using SAS v9.2 (Cary, NC).
37 Patients, 21 males and 16 females, participated in this study, yielding a total of 43 implants and corresponding single-tooth implant supported restorations. Of those 37 patients, 3 patients were African American, 1 patient was Hispanic, and the remainder was Caucasian (33 patients, see Table #1). Of the 43 implants included in this investigation, 6 patient cases were evaluated having multiple (2) non-adjacent single-tooth implant-supported restorations; 4 patient cases assessed implants in the #7 (maxillary right lateral incisor) and #10 (maxillary left lateral incisor) positions; 2 patient cases assessed implants in the #6 (maxillary right canine) and #11 (maxillary right canine) positions; therefore, a total of 31 implants were evaluated as solitary implants in the anterior maxillary region (see Table #2).
<table>
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<tr>
<th>Study Variables</th>
<th>N = # of Implants</th>
<th>% Study Population Based on Implants</th>
<th>N = # of Patients</th>
<th>% Study Population Based on Patients</th>
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</tr>
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<td>26</td>
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<td>Biohorizons</td>
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<td>Zimmer</td>
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<td>12%</td>
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<td>11%</td>
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<tr>
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<td>5%</td>
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<tr>
<td>&gt; 60 months</td>
<td>6</td>
<td>14%</td>
<td>6</td>
<td>16%</td>
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</table>
Of the 43 implants evaluated in this study, 3 implants (6.98% of implants) failed to fulfill Albrektsson’s criteria for success. Of the 3 failures, all were associated with crestal bone loss greater than 0.2mm per year after accounting for 1mm of crestal bone loss due to physiologic remodeling after the first year in function. Therefore, functional success was achieved in 93.02% of the implants assessed in this investigation, according to the parameters of Albrektsson’s criteria.

Of the 43 implants, adequate papilla fill (75-100% papilla fill present with both mesial and distal papillae) was found with 27 of those implants, which correlates to a 63% success rate on papilla fill; therefore 37% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting inadequate papilla fill (less than 75% papilla fill with either mesial or distal papillae) and contributing to overall esthetic deficiency.
Soft tissue height symmetry (with the contralateral reference tooth) was found with 18 out of the 43 implants, which correlates to a 42% success rate on soft tissue height assessment; therefore 58% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting soft tissue height discrepancy (1mm or more of asymmetry with the contralateral reference tooth) and contributing to overall esthetic deficiency.

Absence of hard/soft tissue deficiency (with the adjacent gingival areas) was found with 37 out of the 43 implants, which correlates to a 86% success rate on hard/soft tissue assessment, apical to the implant restoration in question; therefore 14% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting hard/soft tissue deficiency (obvious deficiency upon visual inspection and palpation of the gingival region apical to the implant restoration) and contributing to overall esthetic deficiency.

Adequacy of soft tissue thickness (1mm or more of thickness) was found with 33 out of the 43 implants, which correlates to a 77% success rate on soft tissue assessment of the peri-implant sulcus in question; therefore 23% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting inadequate soft tissue thickness (less than 1mm of thickness as determined by periodontal probe visibility) and contributing to overall esthetic deficiency.
Gingival color/texture symmetry (with the adjacent gingival areas) was found with 20 out of the 43 implants, which correlates to a 47% success rate on gingival color/texture assessment, apical to the implant restoration in question; therefore 53% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting color/texture deviation from the adjacent gingival areas and contributing to overall esthetic deficiency.

Absence of trans-gingival gray discoloration (with the adjacent gingival areas) was found with 28 out of the 43 implants, which correlates to a 65% success rate on trans-gingival hue assessment, apical to the implant restoration in question; therefore 35% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting gray trans-gingival discoloration when compared to the adjacent gingival areas and contributing to overall esthetic deficiency.

Absence of gingival recession was found with 36 out of the 43 implants, which correlates to an 84% success rate on recession assessment; therefore 16% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting gingival recession (1mm or more of recession or appearance of the underlying titanium abutment/implant body) and contributing to overall esthetic deficiency.

Absence of bleeding upon probing was found with 42 out of the 43 implants, which correlates to a 98% success rate on BOP assessment; therefore 2% of the implants evaluated in this investigation failed to meet this parameter, thus exhibiting immediate or
delayed bleeding upon probing and potentially compromising the soft tissue integrity and esthetic appearance of the peri-implant gingival tissues.

Peri-implant pocket depths of 4mm or less were found with 35 out of the 43 implants, which correlates to an 81% success rate on PPD assessment; therefore 19% of the implants evaluated in this investigation failed to meet this parameter, thus exhibiting pocket depths greater than 4mm and potentially compromising the soft tissue integrity and esthetic appearance of the peri-implant gingival tissues.

Incisal edge symmetry (with the contralateral reference tooth) was found with 33 out of the 43 implants, which correlates to a 77% success rate on incisal edge assessment; therefore 23% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting incisal edge discrepancy (1mm or more of asymmetry with the contralateral reference tooth) and contributing to overall esthetic deficiency.

Acceptable crown contours (when compared to the adjacent and contralateral reference teeth) were found with 32 out of the 43 implants, which correlates to a 74% success rate on crown contour assessment; therefore 26% of the implants evaluated in this investigation failed to meet this esthetic parameter, thus exhibiting crown contour irregularity (when compared with the adjacent and contralateral reference teeth) and contributing to overall esthetic deficiency.
Patient satisfaction (determined through patient assessment) was found in all 37 patients, corresponding to a patient-determined acceptable level of function and esthetics achieved with all 43 single-tooth implant-supported restorations in this study. Comments in reference to the existing esthetics of the adjacent teeth in the anterior maxillary region were kept separate and had no bearing on the reported level of satisfaction achieved with the implant restoration in question.

The aforementioned findings were summarized and formulated into the bar chart below (see Table #3), which displays the negative implant restoration characteristics and % incidence found within our study population reported in this investigation:

Table #3: Individual Variable Assessment
Global esthetic assessment was performed by an expert panel consisting of four periodontists and one prosthodontist. Esthetic success was determined by each member of the panel and recorded as follows: 15Y/43 (35%), 14Y/43 (33%), 15Y/43 (35%), 12Y/43 (28%), and 4Y/43 (9%). The lowest esthetic tabulation (4Y/43) was concluded by the sole prosthodontist of the panel. On average, 28% of the implants (12 of 43) included in this investigation achieved esthetic success, which corresponds to a 72% overall esthetic failure rate. On average, 11 of the 43 implants (26%) did not achieve esthetic success due to soft tissue contours, 8 of the 43 implants (19%) did not achieve esthetic success due to prosthetic contour, and 12 of the 43 implants (28%) did not achieve esthetic success due to a combination of both components. 23 of the 43 implants (53%) in this study were deemed failures due to partial involvement of the soft tissue contours, whereas 20 of the 43 implants (47%) were deemed failures due to partial involvement of the prosthetic contours.

Inter-examiner agreement was calculated from the overall esthetic scores of the expert panel. 6 implant cases had 100% inter-examiner agreement, 11 implant cases had 80% inter-examiner agreement, 12 implant cases had 60% inter-examiner agreement, and 14 implant cases had less than 60% inter-examiner agreement.

Approximately 75% (32 out of the 43 implants) were deemed to be an esthetic failure by 3 or more examiners on the expert panel. Approximately 6.98% (3 of the 43 implants) of the implants examined in this study failed to meet Albrektsson’s criteria for
implant success. All of these implants (3 of the 43 implants) were judged to be esthetically unsuccessful by 3 or more examiners on the expert panel. The association between function and esthetic was not statistically significant in this investigation. Therefore, there appears to be no association between single-tooth implant-supported restorations in the anterior maxilla that meet Albrektsson’s implant success criteria and those restorations that meet esthetic success standards as determined by a global esthetic assessment. Implant restorations that fulfill functional success parameters do not necessarily translate into the achievement of esthetic success.

<table>
<thead>
<tr>
<th></th>
<th>Esthetic Success</th>
<th>Esthetic Failure</th>
<th>P-value</th>
</tr>
</thead>
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<td><strong>Soft Tissue Success %</strong></td>
<td>25.58% (N = 11)</td>
<td>23.26% (N = 10)</td>
<td>p&lt;0.001</td>
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<td><strong>Soft Tissue Failure %</strong></td>
<td>0</td>
<td>51.16 (N = 22)</td>
<td>p&lt;0.001</td>
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<table>
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<th>Esthetic Success</th>
<th>Esthetic Failure</th>
<th>P-value</th>
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<td><strong>Prosthetic Success %</strong></td>
<td>25.58% (N = 11)</td>
<td>34.88% (N = 15)</td>
<td>p&lt;0.001</td>
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<tr>
<td><strong>Prosthetic Failure %</strong></td>
<td>0</td>
<td>39.53% (N = 17)</td>
<td>p&lt;0.001</td>
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</table>

According to the statistical analysis (see Table #4), soft tissue success was correlated to esthetic success in 25.58% (N = 11) of all implants. Similarly, prosthetic success was correlated to esthetic success in 25.58% (N = 11) of all implants. Soft tissue success was correlated to esthetic failure in 23.26% (N = 10) of all implants whereas...
prosthetic success was correlated to esthetic failure in 34.88% (N = 15) of all implants.

Soft tissue failure was correlated to esthetic failure in 51.16% (N = 22) of all implants.

Prosthetic failure was correlated to esthetic failure in 39.52% (N = 17) of all implants.
CHAPTER 5
DISCUSSION

Study Demographics

Our investigation evaluated 43 single-unit implant-supported restorations in the anterior maxillary region in 37 patients treated in the Graduate Periodontology and Prosthodontic clinics at the University of Alabama at Birmingham. Based upon the study population assessed in this study, 57% of the patients were male (vs. 43% female) and the majority of patients examined were within the 61-70 year old age group (38% of the patient population) as well as the 71-80 year old age group (38% of the patient population), accounting for 76% of all patients. 89% of the patient population was Caucasian, 8% were African American, and only 3% were Hispanic. 95% of the patients reported a negative tobacco history and 89% were non-diabetic. These last two known risk factors (smoking & diabetes) indicate that our patient population was relatively healthy with minimal systemic involvement that might alter the overall functional and esthetic success of the implants in this study.

Based on 43 total implants analyzed in this study, 46% of all implants were located in the lateral incisor position (23% at #7 site and 23% at #10 site), followed by
the canine position (32% overall, 16% at #6 site and 16% at #11 site), and the central incisor position (21% overall, 9% in #8 site and 12% at #9 site). 63% of all implants placed were Nobel Biocare fixtures, followed by Biohorizons (19%), and Zimmer (12%). The majority of the implants placed in this study were less than 4mm in diameter (60% of all implants) and were within a length range of 13-13.9mm (47% of all implants). The majority of the implants in this study were assessed 12-24 months after restoration delivery (51% of all implants) and 25-36 months after implant placement (26% of all implants). Since our most frequently evaluated implant occurred in the lateral incisor position (46% of all implants), it follows suit that the most common diameter (<4mm) and length (13-13.9mm) found in this study would conform to the size parameters of a lateral incisor, which is commonly replaced by a long and narrow platform implant fixture.

Functional Success and Failure

93.02% of all implants included in this study were functionally successful according to Albrektsson’s success criteria. 6.98% of all implants were functional failures according to the same criteria. A failed implant has been described as one that is clinically mobile. In contrast, an implant that shows progressive loss of supporting bone, but that is clinically immobile, is a failing implant. Early implant failures denote a lack of initial integration while late failures and failing implants occur after initial integration, physiological remodeling, and loading. Problems limited to the soft tissues surrounding implants and not involving the supporting bone have been defined as “ailing implants”
and, more recently, as biological complications. Endosseous dental implants rarely fail beyond the first year after restoration.

Literature studies show excellent survival rates of single-tooth restorations on dental implants, varying from 96.1% to 98.9% after 7.5 years in function (Creugers et al. 2000). Multi-year studies of implants in partially edentulous patients have generally reported greater than 90% success rates for both maxillary and mandibular implants. The implant survival meta-analysis on implants in the esthetic zone up to 1 year after implant restoration, revealed an overall survival rate of 95.5% [95% CI: (93.0–97.1)] irrespective of the type of intervention. It should be stated that, with respect to the loss of implants that are more than 1 year in function, a very low event rate was calculated as 0.007 [95% CI: (0.003–0.019)]. In our investigation, functional success was determined to be 93.02%, which is comparable to the overall survival rate of implants in the anterior esthetic zone (95.5%) found within the meta-analysis mentioned above.

Papilla Fill

37% of all implants exhibited inadequate papilla fill (less than 75% papilla fill with either mesial or distal papilla) according to the parameters of our evaluation. According to Furhauser’s study of the pink esthetic score (PES), complete papilla fill was achieved in 62% (mesial papilla) and 56% (distal papilla) of all cases (N = 30) in their first assessment, and in 58.8% (mesial papilla) and 51.6% (distal papilla) of all cases (N = 30) in their second assessment. The average of these two assessments yielded
complete papilla fill in 60.4% (mesial papilla) and 53.8% (distal papilla) of all cases, with an overall papilla fill of 57.1%. Therefore, the PES investigation demonstrated inadequate papilla fill in 42.9% of all cases, which is comparable to the findings in our study (37% inadequate papilla fill).97

The one variable reported to be most important for peri-implant esthetics in the literature, i.e. the papilla, was most often restored to match that of natural teeth. Our study showed inadequate papilla fill in 37% of all cases, whereas the PES study showed inadequate papilla fill in 42.9% of all cases. These findings suggest that more than 50% of all cases exhibited acceptable papilla fill. The majority of studies reported in the Gehrke et al. article show that the soft tissue between an implant supported single-tooth reconstruction and the adjacent teeth has a substantial influence on the esthetic outcome from the patient’s and clinician’s point of view.20 This may well suggest that awareness of the importance of the peri-implant soft-tissue variable improves therapeutic approaches and outcomes.97

Single-implant cases obviously take benefit of tissue support of the adjacent dentition (Grunder 2000, Kan et al. 2003b, Belser et al. 2004).27 When considering the heights of interimplant papillae for instance, studies indicated that these papillae might show inadequacy for complete enclosure of the interimplant area with soft-tissue, thereby failing to duplicate the interproximal soft-tissue appearance of the adjacent teeth (Tarnow et al. 1992, 2003, Lee et al. 2005).27 This deficiency may affect the esthetic outcome unfavorably. The soft tissue height proximal to single-implants is on average much
higher and is related to the interproximal bone level at the side of the adjacent teeth (Grunder 2000, Kan et al. 2003b). Hence, single-implant therapy may lead to more favorable treatment outcomes. The findings of our study (37% inadequate papilla fill) suggest that in more than 50% of all implants evaluated, adequate papilla fill/height was achievable, mainly due to intact adjacent bone support.

Several studies (Schropp et al. 2005a, Romeo et al. 2008, Jemt 1997) have revealed that an increase of tissue volume in the embrasures could be observed during follow-up. For instance, Jemt & Lekholm (2003) found a mean papilla index of 1.1 at crown placement (score 1 and 2 denote, respectively, less than half of the height and at least half of the height of the proximal area filled by soft tissue) while at 2 year follow-up a mean score of 2.4 was found (score 3: complete closure of proximal space with soft tissue). The majority of the papillae analyzed were associated with papilla index scores of 2 or 3 after follow-up, but no significant differences were observed between the different test and control groups. Considering that the majority of implants in our study were evaluated 12-24 months after restoration delivery (51% of all implants), further improvement in papilla fill may be a possible finding with future follow-up.

Soft Tissue Height Discrepancy

58% of all implants exhibited a soft tissue height discrepancy (1mm or more of asymmetry with the contralateral reference tooth) according to the parameters of our evaluation. According to Furhauser’s PES study, symmetrical soft tissue margins were
achieved in 42.3% of all cases (N = 30) in their first assessment, and in 44.5% of all cases (N = 30) in their second assessment. The average of these two assessments yielded symmetrical soft tissue margins in 43.4% of all cases. Therefore, the PES investigation demonstrated soft tissue marginal discrepancies in 56.6% of all cases, which is very similar to the findings in our study (58% soft tissue height discrepancy).\(^97\)

According to the PES study, the level of the soft-tissue margin (56.6% of cases with discrepancy) and the color of the peri-implant soft-tissue (58.8% of cases with color deviation, 53.9% of cases with soft-tissue color/texture deviation) fared the worst in their assessment.\(^97\) In our assessment, the level of the soft-tissue margin (58% of cases with discrepancy) and the color/texture of the peri-implant soft-tissue (53% of cases with color/texture deviation) fared the worst as well. Schropp et al. (2005a) reported that the level of the marginal peri-implant mucosa was acceptable in significantly more cases where implants were installed in early healed extraction sites compared with conventionally healed sites; of the latter almost two thirds of the crowns were assessed to be too short.\(^27\) This may suggest that these parameters should be given more attention when considering how to achieve optimal esthetics with single-tooth implant-supported restorations.

The gingival zenith (soft tissue margin) represents the most apical part of the clinical crown. It also represents both the faciolingual and the mesiodistal location of the crown in relationship to the edentulous ridge. As such, it has a remarkable influence on the morphology of the planned restoration. The gingival zenith affects other objective
criteria, including the balance of gingival levels (too inferior or superior), the tooth axis (too distal or mesial), the tooth dimension (too inferior or superior), and the tooth form (triangular becomes ovoid if too inferior). Without the control of the gingival zenith, the clinician’s ability to define dental implant esthetics is vastly diminished.  

At least four factors affect the gingival zenith. One is, of course, the relative location of the tissues to the planned gingival zenith. Second is the depth of the dental implant placement. Third is the response of the buccal bone and mucosa to the implant procedure and components. The fourth is the prosthodontic management of the gingival zenith architecture. Ideally, the planned gingival zenith is symmetric with the contralateral tooth and harmonious with the gingival levels of adjacent teeth.

The technique of tissue modeling with subgingival crown contours intentionally forces the gingival margin out to the buccal to align it with and mimic the tissue along the adjacent natural teeth. This tipping to the buccal also elevates the gingival margin in an apical direction. Therefore it is imperative that the surgeon maintain gingival thickness and contour when placing and exposing the implant. Following exposure of the implant, the bucco-gingival margin around the healing abutment may be apical to, even with, or coronal to the gingival margins on the adjacent natural teeth. If the beginning point of the gingival margin is apical to its natural counterpart, there will be no option but to fabricate a restoration that is longer than desired for bilateral symmetry.
**Hard/Soft Tissue Deficiency**

14% of all implants exhibited a hard/soft tissue deficiency (obvious deficiency upon visual inspection and palpation of the gingival region apical to the implant restoration) according to the parameters of our evaluation. According to Furhauser’s PES study, absence of alveolar process deficiency was achieved in 54% of all cases (N = 30) in their first assessment, and in 49.1% of all cases (N = 30) in their second assessment. The average of these two assessments yielded an absence of alveolar process deficiency in 51.6% of all cases. Therefore, the PES investigation demonstrated alveolar process deficiency in 48.4% of all cases. In our study, hard and soft tissue deficiencies were assessed as one entity, yielding an overall deficiency of 14% of cases. No definitive correlations can be drawn from these findings.97

In the past, hard and soft tissue deficiencies at the labial aspect resulted in implant placement that was lingual to the ideal aforementioned position. Currently, labial deficiencies can be corrected surgically with high success rates and should not be a reason for lingual positioning of the platform.30 The only reason for placing the platform slightly to the lingual aspect is if the clinician’s method of choice is a screw-retained prosthesis.30 However, one has to be careful positioning the implant lingually. Placing the implant too far to the lingual aspect will result in a restoration that has an abrupt buccal emergence profile, which does not facilitate proper oral hygiene.30

If the ideal gingival zenith is greater than 3 mm incisal and 2 mm buccal from the existing bone crest, then bone augmentation procedures may be considered in addition to
gingival grafting in order to correct for any hard/soft tissue deficiencies. The gingival zenith, therefore, becomes the therapeutic reference point when evaluating ridge morphology defects. A positive esthetic result is suggested when the adjacent tooth attachment levels are intact and there is adequate bone relative to the reference point.

Without underlying bone to support the buccal contour in full dimension, the esthetic volume of the edentulous space ultimately will be deficient. Based on the location of the planned gingival zenith, therefore, decisions regarding the need for bone augmentation, socket preservation, and/or soft tissue augmentation procedures can be prudently accessed. In our study, only 14% of all implants demonstrated hard/soft tissue deficiency, which may imply that the importance of site development is already a well understood concept.

**Adequacy of Soft Tissue Thickness**

23% of all implants exhibited inadequate soft tissue thickness (less than 1mm of thickness as determined by periodontal probe visibility) according to the parameters of our evaluation. Soft tissue thickness can be correlated to the tissue biotype of the peri-implant mucosa. A thin scalloped periodontium is found in less than 15% of cases and is characterized by a delicate soft tissue curtain, a scalloped underlying osseous form, possible dehiscences and/or fenestrations, and a reduced quantity and quality of keratinized mucosa. This form of gingiva reacts to insults by receding facially and interproximally. As recession occurs and the inter-radicular bone resorbs, the subsequent
soft tissue loss compromises the overall esthetic result. When soft tissue thickness is less than 1 mm, a thin scalloped periodontium is likely present with comparable occurrence rates (15% occurrence of a thin scalloped periodontium vs. 23% occurrence of inadequate soft tissue thickness). Since this type of tissue biotype responds to insults by recession, a possible association between the rate of inadequate soft tissue thickness (23%) and the rate of recession (16%) found in our study may be made.

Soft Tissue Color/Texture Deviation

53% of all implants exhibited soft tissue color/texture deviation from the adjacent gingival areas, according to the parameters of our evaluation. According to Furhauser’s PES study, symmetrical soft tissue color was achieved in 45.3% of all cases (N = 30) in their first assessment, and in 37.1% of all cases (N = 30) in their second assessment. The average of these two assessments yielded symmetrical soft tissue color in 41.2% of all cases. Symmetrical soft tissue texture was achieved in 53.1% of all cases (N = 30) in their first assessment, and in 49.1% of all cases (N = 30) in their second assessment. The average of these two assessments yielded symmetrical soft tissue texture in 51.1% of all cases. Therefore, the PES investigation demonstrated soft tissue discoloration in 58.8% of all cases as well as soft tissue texture deviation in 48.9% of all cases. By combining these two parameters, overall soft tissue color/texture deviation was found in 53.9% of all cases, which is very similar to the findings in our study (53% soft tissue color/texture deviation). Soft tissue color/texture fared poorly in both our study and in the PES study, which may suggest that this parameter should be given more attention when
considering how to achieve optimal esthetics with single-tooth implant-supported restorations.

According to the Gehrke et al. study regarding the reproducibility of the Implant Crown Aesthetic Index, outcomes for the anatomic shape, color, and texture of the peri-implant mucosa obtained a poorer score than other parameters. In a study reported in the Cooper et al. article, the color of the periimplant soft tissue matched that of the reference tooth in no more than just over one-third of cases. Our study, in comparison, found soft tissue color/texture deviations in 53% of all cases, which may further suggest that the peri-implant mucosa requires thorough consideration in achieving overall esthetic success.

Trans-Gingival Discoloration

35% of all implants exhibited gray trans-gingival discoloration (when compared to the adjacent gingival areas) according to the parameters of our evaluation. According to Furhauser’s PES study, symmetrical soft tissue color was achieved in 45.3% of all cases (N = 30) in their first assessment, and in 37.1% of all cases (N = 30) in their second assessment. The average of these two assessments yielded symmetrical soft tissue color in 41.2% of all cases. Therefore, the PES investigation demonstrated soft tissue discoloration in 58.8% of all cases. In our study, gray trans-gingival discoloration (35%) was assessed separately from soft tissue color/texture deviation (53%). No definitive correlations can be drawn from these findings.
There is a limit to the implant width that a buccal cortical plate at a given site can accommodate. Even if there is room for a very wide implant, the superficial placement of this wide platform may result in an optical reflection, a “show through,” of the implant through the thin bony plate. Once created, such an esthetic deficiency cannot be corrected. Replacement of a tooth in the anterior maxillary region often relies on the use of a regular or narrow platform implant, which might avoid the previously mentioned problems with trans-gingival discoloration.

The soft tissues must be carefully considered when planning implants in the anterior maxillary region in order to avoid any gray trans-gingival discoloration. Thin, friable, poorly keratinized tissues are more susceptible to inflammatory and mechanical insult. This can be potentially disastrous in an esthetically demanding area, because post-restorative recession will compromise even the most well-fabricated restoration. These tissues are also highly susceptible to a “graying effect” from the underlying implant body or abutment as it passes from the bone crest toward the peri-implant sulcus. Although this problem is often eliminated via soft tissue grafting, such an approach is impractical if it will result in a greater buccal bulk around the implant than around the adjacent teeth.
Recruitment

16% of all implants exhibited gingival recession (1mm or more of recession or appearance of the underlying titanium abutment/implant body) according to the parameters of our evaluation. According to the Furhauser article, Sheller et al. (1998) reported recession in 10% of the implant-supported single-tooth replacements that they evaluated, which is comparable to the findings of our study (16% of all cases with recession present).97

Achieving optimal gingival esthetics around anterior single implants is a challenging procedure and maintaining it over time can be an equally demanding task. Despite the high success rates achieved with osseointegrated implants,6-12 the peri-implant mucosal response is not clearly understood. For anterior single implants, up to 16% of gingival recession has been previously reported.101 On the other hand, spontaneous rebound of the receded gingiva has also been observed following a few years of function.101 The peri-implant mucosa changes had been postulated as an attempt to establish a stable biological dimension.101 Peri-implant mucosa, like its natural teeth counterpart (the dentogingival complex), comprises similar histologic components (gingival sulcus and connective tissue attachments) and dimension (~ 3 mm).101 While the dimension of each component may change over time, these changes do not significantly affect the overall dimension.101

The risk of recession may potentially increase if a number of factors are not considered. These factors may included but should not be limited to the following:
initial presentation (Seibert classification), implant position capability (relative to planned gingival zenith), bone formation and resorption at the implant, peri-implant mucosa integration, character of the implant abutment interface, inflammation, local factors (plaque, etc.), patient factors (e.g., biotype), abutment form, submucosal contour of the provisional crown, bone modeling/remodeling, and potential adjacent tooth eruption.28

Bleeding Upon Probing

2% of all implants exhibited immediate or delayed bleeding upon probing according to the parameters of our evaluation. According to the Hartog et al. article, studies that assessed the presence of plaque on the surfaces of the implant restoration showed high variance in outcome from 0.5% to 61% of sites examined. Accordingly, the same phenomenon could be observed with bleeding upon probing.27 Therefore, even when plaque is present as an etiological factor and BOP has been identified around the peri-implant mucosa, greater likelihood with BOP inconsistencies may occur.

The biologic width is made up, as one proceeds coronally, of connective tissue attachment to root cementum, followed by a hemidesmosomal attachment of the junctional epithelium to the root, and followed by the gingival sulcus.100 The biologic width serves a number of protective functions. If impinged upon by restorative materials and not corrected, an inflammatory process often ensues and bleeding upon probing may become readily evident. Implant restorations need to adhere to the principles of biologic
width in order to minimize biological impingement upon the attachment to the implant. Violation of biologic width may be correlated to the presence of BOP and should be avoided in order to maintain the health of the peri-implant mucosa.

**Periodontal Pocket Depth**

19% of all implants exhibited pocket depths greater than 4mm according to the parameters of our evaluation. According to the Hartog et al. article, a study by Schropp et al. (2005b) observed a mean reduction in probing depth of 0.5mm during a 2-year observation period to a mean probing depth of 4.2 mm for single-unit implant-supported restorations in the anterior maxilla. The mean probing depths presented by other studies within the article were clearly lower. These studies support the notion of 4mm being clinically compatible with peri-implant health.

Lang and co-workers demonstrated that, as the degree of inflammation in the soft tissues increased, the probe penetration into the periimplant sulcus exceeded the connective tissue level by an average of 0.52mm. Ericsson and Lindhe also demonstrated a lesser resistance to probing the peri-implant mucosa, as compared to probing the periodontal sulcus. This is due to the lack of a true connective tissue attachment to the implant surface. Such vulnerability further underscores the need to provide the patient with a cleansable, maintainable peri-implant milieu. Nonetheless, greater probing depth around an implant compared with a natural tooth may be due to a lack of a true attachment or the presence of inflammation in the peri-implant mucosa.
Probing depths around implants may be of little diagnostic value, unless accompanied by pathologic signs (e.g., radiographic radiolucencies, purulent exudate, bleeding) and/or symptoms (e.g., discomfort, pain). The benefit of probing the implant sulcus has been challenged in the literature because sound scientific criteria are lacking. On one hand, probing not only measures pocket depth, but also reveals tissue consistency, bleeding, and the presence of exudate. Increasing probing depths over time may indicate bone loss, but not necessarily indicate disease for an endosteal implant. Stable, rigid, fixated implants have been reported with pocket depths ranging from 2 to 6 mm. Lekholm et al. found that the presence of deep pockets was not accompanied by accelerated marginal bone loss. Conversely, studies have shown that sulcus depths greater than 5 to 6 mm around implants have a greater incidence of anaerobic bacteria and may require intervention in the presence of inflammation or exudate (e.g., surgery, antibiotic regimens). Overall, healthy, partially edentulous implant patients consistently exhibit greater probing depths around implants than around teeth.

The potential for damage to the fragile attachment or marring of the implant surface may exist during probing. On the other hand, there is no clinical or experimental evidence supporting this hypothesis. Routine probing depths are not suggested in the absence of other signs or symptoms and may be related to the presence of local disease or preexisting tissue thickness before the implant was inserted. Future
research in the area of probing is needed before including this as a primary criterion in a consensus for success, survival, and/or failure.

**Incisal Edge Discrepancy**

23% of all implants exhibited an incisal edge discrepancy (1mm or more of asymmetry with the contralateral reference tooth) according to the parameters of our evaluation. According to the Gehrke et al. study regarding the reproducibility of the Implant Crown Aesthetic Index, very good ratings below one point (0 = excellent, 1 = satisfactory) were given relatively often for the outcome of the position of the incisal edge.  

Our study, in comparison, found an incisal edge discrepancy in less than one-fourth (23%) of all cases, which may suggest that the restorative dentist assigned to each case fabricated the final implant-supported restoration with careful consideration for incisal edge symmetry more frequently than expected.

Jemt & Lekholm (2005) reported that majority of implant crowns were on average 0.7mm longer than the contralateral natural crowns after 5-year follow-up. The same value was recorded by Gotfredsen (2004) after 5-year and he found that 17 of the 20 (85%) implant crowns were too long. These findings do not agree with the findings of Gehrke et al. as well as the findings of our investigation (23% of all implant restorations exhibited incisal edge discrepancy). The incisal edge position is contingent upon the adjacent incisal edges as well as the incisal edge of the contralateral reference tooth. Therefore, existing adjacent and contralateral esthetics of the natural dentition...
may play an important role in this determination and if the esthetics (the incisal edges more specifically) is not optimal in both regions, a higher rate of discrepancy or variation may be noted.

Crown Contour/Color Irregularity

26% of all implants exhibited crown contour irregularity (when compared the adjacent and contralateral reference teeth) according to the parameters of our evaluation. According to the Gehrke et al. study regarding the reproducibility of the Implant Crown Aesthetic Index, very good ratings below one point (0 = excellent, 1 = satisfactory) were given relatively often for the outcomes of the mesiodistal dimension and labial convexity of the final restoration. Our study, in comparison, found crown contour irregularities in approximately one-fourth (26%) of all cases, which may suggest that the restorative dentist assigned to each case fabricated the final implant-supported restoration with careful consideration for appropriate crown contours more frequently than expected.

Patient Satisfaction

100% of all implants satisfied patient expectations according to patient-determined acceptable levels of function and esthetics. In a study by Baracat et al. of patient expectations before and after dental implant therapy, the patients’ esthetic and functional post-treatment ratings of dental implant therapies were significantly higher than their expectations before these therapies. This may suggest that low pre-treatment
expectations in either study may affect the potential overall acceptance of esthetics post-treatment. Pjetursson and colleagues reported that 92% of their patients stated that implant dental therapy outcomes satisfied their expectations, which is comparable to the findings of our study (100% patient satisfaction).\textsuperscript{103}

Chang and colleagues\textsuperscript{23} interviewed dentists and patients to evaluate the esthetic outcome of implant supported single-tooth restorations using standardized questionnaires. The results confirm a high level of patient satisfaction with the outcome of treatment. The picture was contradictory in the assessment of these patient cases by prosthodontists, who assigned the treatment outcome a much lower rating than the patients. The author interpreted this result to the effect that the clinicians are either more critical or they apply different standards when assessing esthetic outcome from those applied by the patients involved themselves. In actual fact, a statistical analysis indicated that parameters such as crown shape, contact point position, color, and topography of the surrounding soft tissue had a significant influence on the rating of general satisfaction with appearance, although it was not possible to detect any similar connections within patient questioning.\textsuperscript{20}

It is important to note that many factors appear to influence patient’s attitudes toward dental esthetics, such as culture, education, economy, traditions, dental care system, patient/dentist relationship, media images of dental appearance, among others.\textsuperscript{103} In evaluating patient satisfaction, it is very difficult to account for which factors weigh more heavily. Patient preferences and attitudes are difficult to eliminate from the
esthetic assessment, which may invalidate patient satisfaction ratings in any study of esthetics.

Global Assessment Discussion

Esthetic success was determined by each member of the expert panel and reported as follows: 35% esthetic success (15 of 43), 33% esthetic success (14 of 43), 35% esthetic success (15 of 43), 28% esthetic success (12 of 43), and 9% esthetic success (4 of 43, as determined by the sole prosthodontist on the panel). These findings were compiled in a single assessment as opposed to multiple assessments. According to the Furhauser PES study, two assessments were performed, with the highest score of 14 (most esthetic) less often assigned in the second assessment. The lowest scores (inadequate esthetics) were slightly more often assigned in the second run, suggesting that the observers tended to become more critical in the second assessment. Therefore, in order to eliminate observational bias, only one assessment was performed by our expert panel.

The sole prosthodontist on the expert panel awarded an overall esthetic outcome in only 4 of 43 (9%) implant cases, whereas the four periodontists on the expert panel deemed an esthetic outcome in 32.75% (on average) of all cases. This may suggest that the sole prosthodontist may have been overly critical in the esthetic assessment. According to the PES study, prosthodontists, surgeons, and dental students all scored the outcome significantly more generously, which suggests that no association can be made...
between the specialty groups evaluating each case. Discrepancies found between various occupational groups are probably not only dependent on the examiner’s degree of specialization, but also on individual viewpoints.

Esthetic Success and Failure

Overall esthetic success was achieved with 28% of all implants included in this investigation, prior to statistical assessment. Overall esthetic failure was reported with 72% of all implants included in this study, prior to statistical assessment. According to Meijndert et al. (2007), using the Implant Crown Aesthetic Index developed by Meijer, it was reported that in 34% of the cases, the esthetics were not acceptable, which varies significantly from the results of our study. Therefore, esthetic success variance found between various studies are probably not only dependent on the examiner’s degree of specialization, but also on individual viewpoints, which makes standardization of esthetics and comparisons between studies difficult.

Most studies on implant success still do not provide, or evaluate, criteria for esthetic success, so it is difficult to determine the prevalence of implant failures for esthetic reasons. The few studies in the literature that have reported on esthetic complications reveal that anywhere between 4% and 16% of single implant crowns in the anterior maxilla fail for esthetic reasons. The most common esthetic complication is gingival recession exposing the implant/abutment junction, with one study reporting up to 61% of cases with at least 1 mm of gingival recession on the facial aspect.
addition, poor shade selection for the prosthesis and lack of interdental papillae also account for implant esthetic failures.\textsuperscript{104}

\textit{Failure due to Soft Tissue Component, Prosthetic Component, or Both}

26\% of all implants did not achieve esthetic success due to soft tissue contours only and 53\% of all implants were deemed esthetic failures due to partial involvement of the soft tissue contours, prior to statistical assessment. 19\% of all implants did not achieve esthetic success due to prosthetics only and 47\% of all implants were deemed esthetic failures due to partial involvement of the prosthetics, prior to statistical assessment. 28\% of all implants did not achieve esthetic success due to a combination of both components, prior to statistical analysis.

According to a cross-sectional, retrospective study by Belser and colleagues\textsuperscript{19}, all 45 anterior maxillary single-tooth implants fulfilled strict success criteria for dental implants with regard to osseointegration, including the absence of peri-implant radiolucency, implant mobility, suppuration, and pain. Further evaluation was performed with the pink esthetic score (PES), comprised of the following five variables: mesial papilla, distal papilla, curvature of the facial mucosa, level of the facial mucosa, and root convexity/soft tissue color and texture at the facial aspect of the implant site, in combination with the white esthetic score (WES). The WES specifically focuses on the visible part of the implant restoration itself (i.e., the part of the implant crown that emerges from the peri-implant mucosa) and is based on the five following parameters:
general tooth form; outline and volume of the clinical crown; color, which includes the assessment of the dimension’s hue and value; surface texture, and translucency and characterization.\textsuperscript{19}

The mean total pink esthetic score/white esthetic score was 14.7 – 1.18 (range: 11 to 18, maximum 20). The mean total PES of 7.8 – 0.88 (range: 6 to 9, maximum 10) documents favorable overall peri-implant soft tissue conditions.\textsuperscript{19} In comparison, our investigation found a deficient soft tissue component in 53% of all implants evaluated, suggesting unfavorable peri-implant esthetics. The two PES variables facial mucosa curvature (1.9 – 0.29) and facial mucosa level (1.8 – 0.42) had the highest mean values, whereas the combination variable root convexity/soft tissue color and texture (1.2 – 0.53) proved to be the most difficult to fully satisfy.\textsuperscript{19} Soft tissue color/texture fared poorly in both our study and in this PES/WES study, which may suggest that this parameter should be given more attention when considering how to achieve optimal esthetics with single-tooth implant-supported restorations.

The mean total PES/WES of 14.7 indicated an overall successful esthetic outcome; only one crown scored <12, which was defined as the threshold of clinical acceptability.\textsuperscript{19} In comparison, our study found an overall unsuccessful esthetic outcome (74% esthetic failure before statistical analysis, 75% esthetic failure after statistical analysis), which may be due to the quality of the objective absolute criteria included in our study as well as the method of which esthetics was assessed.
The PES (mean score of 7.8) was clearly higher than the corresponding WES (mean score of 6.9).\(^{19}\) This may be due to the fact that the PES is mainly influenced by the local anatomy and the applied surgical procedure to regenerate the peri-implant bone defects routinely present in post-extraction implant sites. Hence, the routine and skills of the implant surgeon play an important role in the esthetic outcome of peri-implant soft tissues.\(^{19}\)

The WES was clearly less favorable than the PES, which contradicts the findings of our investigation (53% with a soft tissue deficiency vs. 47% with a prosthetic deficiency). This observation is also documented by the fact that 20% of the crowns scored below the threshold of 6, which is the level of clinical acceptability from the examiner’s point of view. It is possible that the WES component of the applied esthetic index is too rigorous, because all patients accepted the insertion of their implant crowns during therapy. The patient’s perception of dental restorations from an esthetic point of view frequently differs significantly from that of dental professionals, which is confirmed by reports from the literature.\(^{19}\)

*Inter-Examiner Agreement*

Inter-examiner agreement was reported in this study as follows: 6 implants with 100% inter-examiner agreement, 11 implants with 80% inter-examiner agreement, 12 implants with 60% inter-examiner agreement, and 14 implants with less than 60% inter-examiner agreement. Disagreement found between the examiners on the expert panel of
this investigation are probably not only dependent on the examiner’s degree of specialization, but also on individual viewpoints,\textsuperscript{20} which may support the lack of agreement identified above.

\textit{Esthetic Success and Failure by 3 or More Experts}

75\% of all implants were deemed to be an esthetic failure by 3 or more examiners on the expert panel. 6.98\% of all implants failed to meet Albrektsson’s criteria for implant success and were also deemed esthetic failures. Therefore, the association between function and esthetic was not statistically significant in this investigation. In conclusion, there appears to be no association between single-tooth implant-supported restorations in the anterior maxilla that meet Albrektsson’s implant success criteria and those restorations that meet esthetic success standards as determined by a global esthetic assessment. Furthermore, implant restorations that fulfill functional success parameters do not necessarily translate into the achievement of esthetic success.

\textit{Soft Tissue & Prosthetic Esthetic Success Characteristics Compared with Overall Esthetic Success}

According to the statistical analysis performed in this study, soft tissue success was correlated to esthetic success in 25.58\% (N = 11) of all implants. This means that when peri-implant esthetics are adequate or ideal, an overall esthetic result may only occur in about a quarter of the study population. This implies that success with soft
tissue characteristics is a contributing factor to overall esthetic success, but it does not dictate or predominantly influence the overall outcome. Soft tissue success was correlated to esthetic failure in 23.26% (N = 10) of all implants, signifying that even when soft tissue contours may have been satisfactory or optimal, esthetics was still not achieved in about a quarter of the study population, as stated above. Soft tissue failure was correlated to esthetic failure in 51.16% (N = 22) of all implants. This means that when soft tissue esthetics are not achieved, overall esthetic failure occurs about 50% of the time. It can be concluded that peri-implant esthetics may have a low positive predictive value (overall esthetic success only 25.58% of the time when successful soft tissue esthetics are achieved) on the esthetic outcome.

According to the statistical analysis performed in this study, prosthetic success was correlated to esthetic success in 25.58% (N = 11) of all implants. This means that when crown esthetics are adequate or ideal, an overall esthetic result may only occur in about a quarter of the study population. This implies that success with prosthetic characteristics is a contributing factor to overall esthetic success, but it does not dictate or predominantly influence the overall outcome. Prosthetic success was correlated to esthetic failure in 34.88% (N = 15) of all implants, signifying that even when prosthetic characteristics may have been adequate or optimal, esthetics was still not achieved in about a third of the study population, as stated above. Prosthetic failure was correlated to esthetic failure in 39.52% (N = 17) of all implants. This means that when crown esthetics are not achieved, overall esthetic failure occurs about 40% of the time. It can be concluded that implant restoration esthetics may have a low positive predictive value.
(overall esthetic success only 25.58% of the time when successful prosthetic esthetics are achieved) on the esthetic outcome. Furthermore, it may be concluded that soft tissue failure may factor more heavily on the overall esthetic failure (51.16%) of single-tooth implant-supported restorations, compared to prosthetic failure (39.52% esthetic failure).

Another similar study evaluated the contribution of surgical, soft tissue, and prosthetic components to overall esthetic success. Juodzbalys and Wang\textsuperscript{98} developed a complex esthetic index (CEI) for rating the esthetics of anterior maxillary implant-supported restorations with respect to the surrounding soft and hard tissues. Fifty patients (31 males and 19 females; age: 18 to 50 years; mean age – SD: 32.4 – 9.1 years) previously treated with dental implants were evaluated regarding the esthetic results of their restorations using the proposed CEI. Two calibrated oral surgeons did the evaluation and recording. The evaluation was carried out twice by each of the examiners 2 weeks apart.\textsuperscript{98}

The proposed complex esthetic index is composed of three components: the soft tissue index (S), predictive index (P), and implant-supported restoration index (R). Within each category, specific parameters were evaluated and graded as adequate (rating 20%), compromised (rating 10%), or deficient (rating 0%). Soft tissue characteristics of the S that were previously published\textsuperscript{8} include soft tissue contour variations, soft tissue vertical deficiency, soft tissue color and texture variations, and mesial and distal papillae appearance. The P primary assessed the following components: mesial and distal interproximal bone height, gingival tissue biotype, apico-coronal position of the
implants, and horizontal contour deficiency. The R evaluated the color and translucency of the implant-supported restoration, labial convexity in the abutment/implant junction, implant/crown incisal edge position, crown width/length ratio, and surface roughness and ridges of the implant-supported restoration in relationship to adjacent and contralateral teeth. All mentioned R parameters, with the exception of crown width/length ratio, must be in harmony with the adjacent and contralateral teeth.\textsuperscript{98}

Accordingly, when the S, P, and R general ratings were adequate, the CEI rating was 100%. When one of the indices registered between 60\% and 90\%, this was a compromised and clinically acceptable result. When the CEI was <50\%, this was a deficient and clinically unacceptable esthetic outcome. An adequate CEI of S100, P100, and R100 was observed by both examiners in 10\% and 12\% of cases in evaluations I and II, respectively.\textsuperscript{98} In comparison, only 25\% of all single-tooth implant-supported restorations in our study achieved overall esthetic success.

Further analysis revealed the importance of each CEI component. It was found that in situations where the CEI was S100, P100, and R (prosthetic component) <100\%, the number of cases was the same as it was using the adequate CEI. When the P (surgical component) was <100\%, the number of cases with adequate S and R was reduced more than twice. When the S (soft tissue component) was <100\%, the number of cases with adequate P and R was significantly reduced.\textsuperscript{98} This may imply that the surgical and soft tissue components of this index outweigh the contribution of the prosthetic component and may require more attention when trying to obtain an esthetic result. From our study,
similar conclusions were drawn as follows: soft tissue failure may factor more heavily on the overall esthetic failure (51.16%) of single-tooth implant-supported restorations, compared to prosthetic failure (39.52% esthetic failure). Hence, soft tissue signifies an important esthetic factor that must be carefully considered in implant dentistry and optimally planned for in the final restorative result.
The conclusions of our investigation are as follows:

1) The association between function and esthetic was not statistically significant in this investigation.

2) There appears to be no association between single-tooth implant-supported restorations in the anterior maxilla that meet Albrektsson’s implant success criteria and those restorations that meet esthetic success standards as determined by a global esthetic assessment.

3) Implant restorations that fulfill functional success parameters do not necessarily translate into the achievement of esthetic success.

4) Soft tissue height (level of the soft tissue margin) and soft tissue color texture may require more attention and consideration when trying to obtain an esthetic result.

5) Soft tissue failure may factor more heavily on the overall esthetic failure (51.16%) of single-tooth implant-supported restorations, compared to prosthetic failure (39.52% esthetic failure)
6) Soft tissue signifies an important esthetic factor that must be carefully considered in implant dentistry and optimally planned for when contemplating single-tooth implant-supported restorations in the anterior maxilla.

The esthetic result is still not systematically included among the implant therapy success criteria, although a tendency to do so is developing in more recently published articles and especially in those that appraise the implant-supported prosthetic rehabilitations of the maxillary and mandibular anterior sectors. It has not been possible to identify an esthetic evaluation index that is commonly approved by clinicians and researchers because the parameters considered are often different between study groups or they are used in various combinations. A common index would be useful not only to assess the success of the therapy as a whole, but also as a valid tool of longitudinal observation of the progressive maturation of the peri-implant soft tissues. It would then be possible to appraise the esthetics not only in terms of purely descriptive dimensional measurements, but also in terms of a progressive matching of the implant-supported prosthetic restoration with the surrounding tissues.

The lack of an encoded index that has been approved by the international scientific community represents a spur to search for a method with which to evaluate the esthetic result that is as far as possible complete, objective, reproducible, reliable, and free from methodological errors (bias). Finally, there is a need to integrate the professional’s “objective” evaluation and the “subjective” evaluation of the patient, the latter harvested by means of satisfaction questionnaires whose answers are quantified on
Visual Analogue Scales (VASs). This would not only establish the degree of agreement or disagreement between the two points of view but would also make the clinician aware of the parameters that would render the implant-supported rehabilitation more esthetically pleasing in the eyes of the patient.
LIST OF REFERENCES

Form 4: IRB Approval Form
Identification and Certification of Research Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federally Wide Assurance with the Office for Human Research Protections (OHRP). The Assurance number is FWA00005960 and it expires on October 26, 2010. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56 and ICH GCP Guidelines.

Principal Investigator: REGANATO, ANTHONY J
Co-Investigator(s): GEISINGER, MARIA
Protocol Number: F080917063
Protocol Title: Aesthetic Criteria Analysis of Single-Tooth Implant-Supported Restorations in the Anterior Maxilla

The IRB reviewed and approved the above named project on 9/23/2009. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received FULL COMMITTEE review.
IRB Approval Date: 9/23/2009
Date IRB Approval Issued: 9/24/09
Identification Number: IRB00000196

Ferdinand Urthaler, M.D.
Chairman of the Institutional Review Board for Human Use (IRB)

Investigators please note:
The IRB approved consent form used in the study must contain the IRB approval date and expiration date.
IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one-year anniversary of the IRB approval date.
Any modifications to the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.
Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.
APPENDIX B

ABSOLUTE CRITERIA EXAMPLES
1) Albrektsson’s implant success criteria: Y = meets all criteria; N = fails any one criterion

**FIG 1A:** Case meets all functional parameters under Albrektsson’s criteria for implant success (Tooth #9)

**FIG 1B:** Case fails to meet functional parameters under Albrektsson’s criteria (Tooth #11); crestal bone loss of 1.41mm/year was determined; restoration had been in function for 22 months
2) Papilla fill: Y = Complete (75-100% papilla fill present); N = Incomplete (<75% papilla fill present)

FIG 2A: Case demonstrates optimal papilla fill and height (75-100% papilla fill present), as determined by clinical assessment

FIG 2B: Case demonstrates inadequate papilla fill and height (<75% papilla fill present), as determined by clinical assessment
3) Soft tissue height discrepancy: Y = present; N = not present

FIG 3A: Case demonstrates soft tissue height discrepancy between the implant restoration (tooth #9, maxillary left central incisor) and the contralateral reference tooth #8 (maxillary right central incisor)

FIG 3B: Case demonstrates soft tissue height symmetry between the implant restoration (tooth #10, maxillary left lateral incisor) and the contralateral reference tooth #7 (maxillary right lateral incisor)
4) Hard/soft tissue discrepancy: Y = present/visible; N = not present/visible

FIG 4A: Case demonstrates hard/soft tissue deficiency apical to the implant restoration (tooth #11, maxillary left canine)

FIG 4B: Case demonstrates optimal hard/soft tissue profile apical to the implant restoration (tooth #10, maxillary left lateral incisor)
5) Adequacy of soft tissue thickness: Y = probe not visible through the gingival tissues (≥1mm thickness); N = probe visible through tissue (<1mm thickness)

FIG 5A: Case demonstrates thin peri-implant biotype, evidenced by trans-gingival discoloration apical to the implant restoration (Tooth #10)

FIG 5B: Case demonstrates thick peri-implant biotype, evidenced by absence of trans-gingival discoloration apical to the implant restoration (Tooth #10) and comparable appearance of the gingival tissues with the adjacent areas
6) Gingival color/texture deviation: Y = deviation evident; N = no deviation noted

FIG 6A: Case demonstrates gingival color/texture deviation apical to the implant restoration (tooth #6, maxillary right canine), when compared to the adjacent tissues;

FIG 6B: Case demonstrates gingival color/texture symmetry apical to the implant restorations (tooth #7, maxillary right lateral incisor, and tooth #10, maxillary left lateral incisor), when compared to the adjacent tissues;
7) Bleeding upon probing: Y = Bleeding upon probing (BOP) present; N = BOP absent

FIG 7A: Case demonstrates bleeding upon probing from the distal-facial aspect of the peri-implant sulcus, associated with the implant restoration (Tooth #7)

FIG 7B: Case demonstrates absence of bleeding upon probing associated with the implant restoration (Tooth #10)
8) Recession: Y = present; N = not present

FIG 8A: Case demonstrates recession apical to the margin of the implant restoration (tooth #9, maxillary left central incisor), corresponding to the appearance of the underlying titanium abutment/implant body seen beyond the gingival margin

FIG 8B: Case demonstrates absence of gingival recession apical to the implant restoration (tooth #10, maxillary left lateral incisor)
9) Incisal Edge Discrepancy: Y = present; N = not present

FIG 9A: Case demonstrates incisal edge discrepancy associated with the implant restoration (tooth #7, maxillary right lateral incisor) when compared to the contralateral reference tooth (#10, maxillary left lateral incisor)

FIG 9B: Case demonstrates incisal edge symmetry with the implant restoration (tooth #7, maxillary right lateral incisor) and the contralateral reference tooth (#10, maxillary left lateral incisor)
10) Crown contour irregularity: Y = irregular contour deviation present; N = irregular contour deviation absent

FIG 10A: Case demonstrates crown contour irregularity, evidenced by an excessively long implant restoration (tooth #9, maxillary left central incisor) with the inclusion of pink porcelain to mimic gingival tissue

FIG 10B: Case demonstrates crown contour symmetry of the implant restoration (tooth #8, maxillary right central incisor) with the contralateral reference tooth (#9, maxillary left central incisor) as well as with the adjacent tooth (#7, maxillary right lateral incisor); optimal crown shade and characteristics are depicted in the image above as well.