Periodontology 2000, Vol. 73, 2017, 193–202
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Esthetic assessments in implant dentistry: objective and subjective criteria for clinicians and patients

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Ample long-term studies have been published demonstrating successful outcome of dental implants placed in partially and fully edentulous patients using various treatment protocols (21, 36, 44, 49). Given the fact that in the early days, implants were mainly used for functional rehabilitation, these papers largely reported on implant and superstructure survival, marginal bone loss and complication rates. Even though these aspects are of key importance, they are incomplete and merely focus on clinicians' judgement.

In the past decade, the scientific community has shown a clear interest in other aspects of treatment outcomes, which reflect the changing demands of an evolving society. Economic and cost-effectiveness analyses have recently been published (3, 20). The first reports are emerging on the impact on speech of different designs of implant-supported prosthesis (74). Moreover, psychosocial parameters have gained considerable attention relating to patient perception of implant treatment and patient preferences (19, 24, 69). These aspects are of key importance because they reflect the patient's judgment. Patient's needs and judgment may differ from objective indicators of implant success and survival. Assessing treatment on the basis of patient-reported outcome measures is an increasingly common aspect of research, in which the evaluation of patient satisfaction is considered crucial.

Esthetics has become a key issue in contemporary practice. The scientific output reflects this phenomenon as the majority of papers on soft-tissue aspects in implant dentistry have been published in the last decade. In these studies, clinicians', as well as patients', critical assessment of esthetics have been reported, sometimes with a distinction between soft-tissue esthetics or so-called 'pink' esthetics (28) and the esthetic appraisal of the superstructure, often referred to as 'white' esthetics (4).

The objective of this paper was to provide an overview of the esthetic ratings that have been used in implant dentistry.

Modern methods to assess esthetics

Overview of esthetic ratings used in implant dentistry: the judgment of the clinician

The esthetic demands of patients provided with tooth- and implant-borne reconstructions have increased over the years. Moreover, the development of new materials and new technologies, together with enhanced knowledge of periodontal and peri-implant biology, have provided the basis for better esthetic outcomes of fixed tooth- and implant-borne reconstructions. These outcomes can be assessed by objective parameters, such as the presence or absence of the papilla, the level of the mucosal margin and two-dimensional and three-dimensional changes of the peri-implant tissues, as well as a reconstruction that matches the color, the shape and the texture of the contralateral natural tooth.

Equal contribution of first and second authors.

In a recent systematic review, parameters and methods were evaluated for the assessment of esthetics in implant dentistry (5). This review identified 181 clinical studies in which one or several methods and parameters were used to evaluate the esthetic outcomes of implant therapy. The large number of studies included in this review reflects the efforts and importance of such outcome measures in today's clinical research. It was reported that scoring systems differed widely between studies, thereby limiting the possibility to compare esthetic outcomes of different studies and therapeutic concepts.

Level of the mucosal margin

Measurement of the level of the mucosal margin relative to the contralateral natural tooth site is one of the methods most frequently used to assess esthetic outcomes (1, 11, 31). Most often this measurement is made in millimeters, using references such as: the cemento–enamel junction; the incisal edge/cusp tips of the teeth examined; the implant shoulder or the incisal edge/cusp of the implant reconstruction; or reference marks on standardized stents (10, 32). Apart from metric measurements, semiquantitative scoring systems were used, comparing the level of the mucosal margin of the implant site with that of a reference tooth site (2, 50, 55). Outcomes were classified into having no difference up to larger differences between the two sites or categorizing into exposition of the crown margin with a simple binomial ranking (yes/no).

Papilla height/embrasure fill

The height of the papilla next to dental implants is one of the main parameters that affects the esthetic outcome of implant therapy and has been reported in numerous studies (6, 12, 56, 66). The embrasure fill has been assessed in millimeters, by measuring the distance between the point of contact between two adjacent teeth and the tip of the papilla (32) or by using a scoring system (57). The following landmarks were frequently used as references: the cemento–enamel junction; the incisal edge/cusp of the adjacent teeth; the implant shoulder; the incisal edge/cusp of the implant-borne reconstruction; and standardized stents. The index most often used evaluated the embrasure fill using a semiquantitative ranking system (35). This index ranks the embrasure fill by applying five possible scores: 0 (no papilla); 1 (< 50% papilla fill); 2 (> 50% papilla fill); 3 (full papilla present); and 4 (hyperplastic papilla).

A variety of factors influence the presence or absence of the papilla. These factors include the anatomy of the neighboring tooth/implant, the implant system, the level of the contact point, the timing of implant placement and the use of a provisional reconstruction. From a clinical point of view, the vertical distance between the alveolar crest and the contact point on the adjacent tooth appears to be the factor that has the most significant influence on the height of the papilla between natural teeth (62). Based on a clinical study analyzing the relationship between this distance and the embrasure fill, the papilla was present in 98% of cases when the vertical distance was 5 mm or less. With increasing distances, the percentage of a full papilla showed a corresponding decrease. This observation was confirmed in a subsequent study on single implants, which attributed the embrasure fill between an implant restoration and the adjacent tooth to the vertical position of the periodontal attachment of the adjacent tooth (9). In cases where the distance between the contact point and the alveolar crest was more than 5 mm, the presence of the papilla was reduced to a frequency of 50%. The anatomy at dental implants is substantially different from that at natural teeth, and inserting Sharpey's fibers are missing around dental implants. This, and the fact that the interdental bone peak resorbs following extraction of adjacent teeth for implant placement, may be considered as the most important reasons for the reduced papilla height between two dental implants (60). Interestingly, the same applies to papilla between an implant and a pontic and, to a lesser extent, to papilla between adjacent pontics (15). Apart from the vertical position, the horizontal distance between the implant and the adjacent tooth also plays a role in determining papilla height. Previous scientific evidence suggests that a minimal distance of 1.5 mm between a dental implant and a neighboring tooth is necessary to compensate for remodeling processes following establishment of the biologic width (26, 27). In the event that two dental implants are placed next to each other, an optimal distance of 3 mm between them was suggested in order to obtain a normal papilla (61). These observations have been predominantly attributed to the implant design and remodeling processes taking place following implant placement and/or abutment connection. One has to bear in mind, however, that most of these data were obtained using implant systems with a one-piece or two-piece design with a matching implant abutment junction. More recent developments in implant dentistry make more extensive use of two-piece dental implants with nonmatching implant–abutment junctions. In two recent preclinical studies, inter-implant distances of 2, 3 and

4 mm demonstrated similar marginal bone loss (22, 23). This indicates that the implant design has an impact on the morphology of the peri-implant tissues. Horizontal distances between two implants and between an implant and a natural tooth might therefore have to be reconsidered and evaluated in the future in well-designed clinical studies.

Two-dimensional and three-dimensional changes in soft-tissue morphology

Today, there was neither consensus nor sufficient evidence with respect to the amount of soft-tissue volume necessary on the buccal side of a dental implant to obtain long-term functional and biological success. Recent studies indicate a relationship between the buccal peri-implant bone height and the level of the mucosal margin (5, 41). Generally speaking, these studies demonstrated slightly more recession with a decreasing buccal bone height. Interestingly, the data demonstrated that peri-implant soft tissues can, at least in part, compensate for missing buccal bone. From an esthetic point of view, and in terms of the color of the peri-implant soft tissues, clinical data suggest a critical bucco-oral soft-tissue dimension of 2 mm (40, 73). Various clinical studies have demonstrated that in cases with less than 2 mm of buccal soft-tissue volume, the choice of reconstruction material can significantly influence the esthetic outcome at implant sites. More favorable results have been reported for all-ceramic reconstructions compared with metal–ceramic reconstructions (39, 52, 76). This, in turn, means that in cases with more than 2 mm of soft tissue in the buccal-oral dimension, the choice of reconstructive material will be less likely to hamper the esthetic outcome (38, 40).

Methods used to assess the buccal soft-tissue dimensions include endodontic files, with or without standardized stents, and ultrasonic devices. In a prospective case series including 37 patients with single missing teeth, dental implants were placed and the soft tissues were augmented with connective tissue grafts (16). The soft-tissue thickness was evaluated using an ultrasonic device at various time-points up to 1 year following implant placement. The data obtained indicate relatively stable soft tissues with a minimal loss of 10%. This type of measurement offers advantages over measurements using endodontic files because it is noninvasive, does not interfere with healing and potentially has better patient acceptance.

To date, little scientific data is available evaluating the peri-implant soft tissues in a three-dimensional way. This is based on the fact that the techniques available to capture volume changes are optimized for hard tissues (i.e. cone beam computed tomography) or are only occasionally used in dentistry (i.e. magnetic resonance imaging). To overcome these shortcomings, a series of preclinical and clinical studies were performed to evaluate the ability of new techniques (including intraoral scanners and the corresponding software tools) to calculate soft-tissue volume changes in a three-dimensional way (54, 59, 70). These techniques have been used to quantify soft-tissue volume changes in single tooth gaps and to measure the height of the papilla (54, 59). Measurements obtained from a three-dimensional image are highly accurate and reliable and thus offer noninvasive ways in which to monitor changes of peri-implant tissues resulting from implant therapy. Apart from assessing the overall three-dimensional volume changes, cross-sectional images allow two-dimensional measurements of soft tissue at various levels below the marginal mucosa (53, 75). Recent scientific evidence demonstrates three-dimensional soft-tissue volume changes over time to correspond strongly to two-dimensional measurements (65, 75).

Color of the peri-implant mucosa and the reconstruction

The appearances of tooth- and implant-borne reconstructions remain a crucial factor for esthetic success. The color match of peri-implant tissues and reconstructions to that of the natural dentition has been described as one of the greatest challenges. Difficulties in color match are attributed to the fact that dental implants and natural teeth, as well as the surrounding soft and hard tissues, differ. Clinically, the use of spectrophotometers has been demonstrated to be one of the best standardized tools to assess the color match: (i) between the peri-implant mucosa and the gingiva of the contralateral/adjacent tooth; and (ii) between the reconstruction and the natural crown of the contralateral/adjacent tooth. A spectrophotometer allows an objective evaluation of the soft-tissue color of tissues and reconstructions. It records digital images that are used for spectral analysis. The data of the measurements are processed and displayed on the indications of the *Commission Internationale de l'Éclairage*, with L referring to lightness, a to chroma along the red–green axis and b to chroma along the yellow–blue axis (48). Images of test sites and control sites are captured and the color differences are calculated. This technique was originally introduced as a color-measuring tool for dental-composite veneers and their surrounding tooth structure (34). Subsequently, a variety of clinical and *in vitro* studies applied spectrophotometric outcome

measures to analyze different materials for use in dental implants and implant-borne reconstructions on the level of the mucosa. Color differences between metal and alumina-reinforced abutments, between metal and zirconia abutments, between zirconia and veneered zirconia abutments and between titanium and zirconia dental implants were calculated (6, 38, 40, 67, 76). Even though sensitive spectrophometric measurements may reveal color differences, clinically, these materials and reconstructions may still fulfill esthetic expectations and subjectively please patients and clinicians. This discrepancy indicates that for the optical perception of color differences, additional factors might have an influence. Based on one study, a clinical threshold value, of 3.7, was calculated for the visibility of color differences (ΔE) by the naked eye (37). Under standardized laboratory conditions, a color difference of about $\Delta E = 1$ in the CIELAB system was defined as a threshold for visibility of color differences (42). More recently, threshold values were recalculated for the gingiva and the tooth substance/reconstruction in standardized settings. The threshold values obtained indicate that: (i) at the level of the mucosa/gingiva, laypeople, dental technicians and dentists have a different perception for color alterations of the gingiva, with the overall threshold (pooled data for laypeople, dentists and technicians) for gingival color differences amounting to a mean ΔE of 3.1 ± 1.5 (51), (ii) however, at the level of the tooth/reconstructions, laypeople, dental technicians and dentists have a similar perception for changes of tooth color, with the overall combining threshold for tooth color differences amounting to a median ΔE of 1.8 (64).

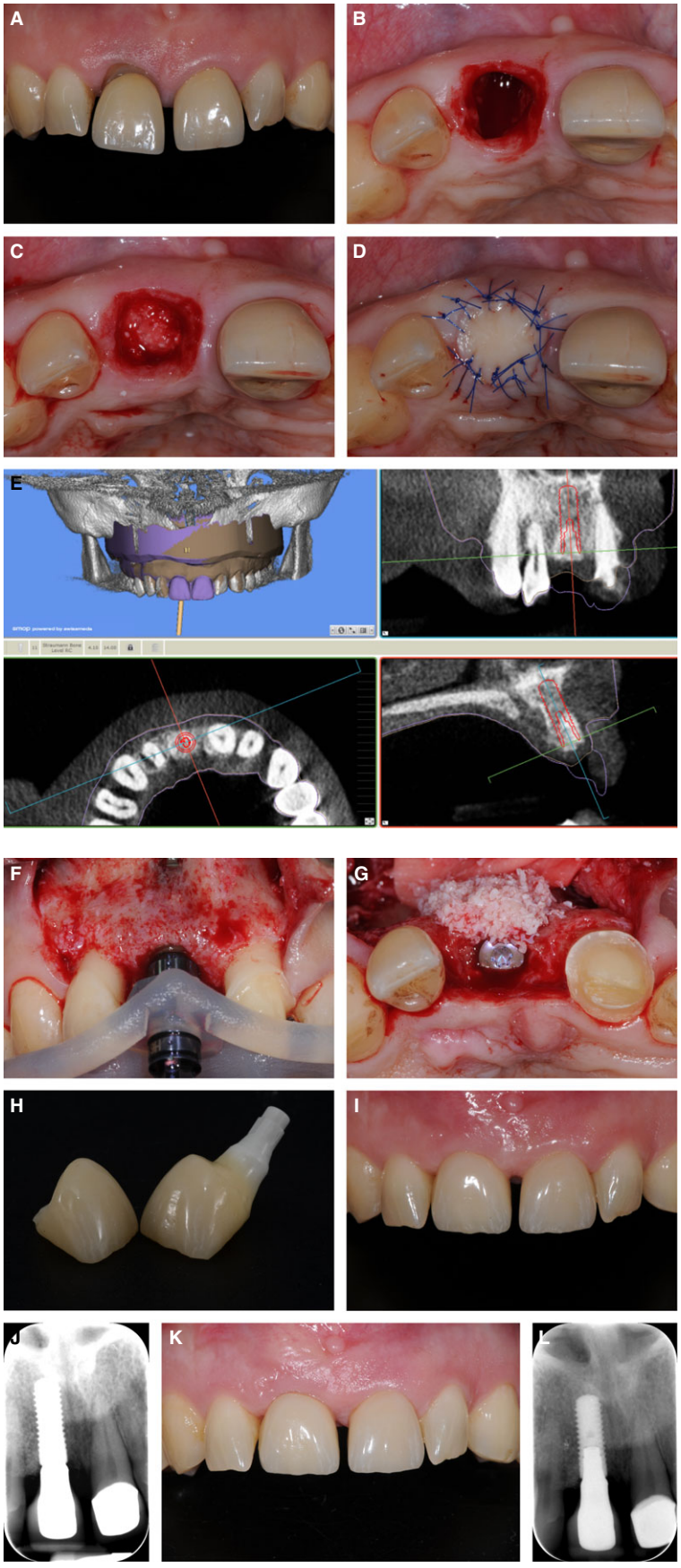
Pink esthetic score/white esthetic score/implant crown esthetic score

In the past, efforts have been made to combine a number of parameters and suggest esthetic scores. The indices primarily applied include the pink esthetic score (28), the white and pink esthetic score (4) and the implant crown esthetic index (46). These three scores can serve as objective measures to assess the esthetic outcomes of implant therapy, at least when evaluating single implants. They can be applied either directly in a clinical setting or on standardized photographs. The pink esthetic score includes a total of seven items: the mesial papilla; the distal papilla; the level of the soft-tissue margin; the soft-tissue contour; possible alveolar process deficiencies; the soft-tissue color; and the soft-tissue texture. For each implant site, a score of 0–2 (0 being the worst value and 2 being the best value) is given, resulting in a maximum score of 14. This index was later combined with an analysis of the reconstruction and led to the so-called pink esthetic score/white and pink esthetic score system. The pink esthetic score/white and pink esthetic score includes 10 items: mesial papilla; distal papilla; curvature of the facial mucosa; level of the facial mucosa; root convexity/soft-tissue color/texture (pink esthetic score); general tooth form; outline and volume of the clinical crown; color; surface texture; and translucency and characterization (white and pink esthetic score). A maximum score of 20 can be obtained (two points for each item). The clinical acceptability threshold of six has been proposed for both pink esthetic score and white and pink esthetic score. Similarly, the implant crown esthetic index includes the peri-implant soft tissue and parameters related to the reconstruction. The reconstructive parameters encompass the mesio-distal dimension of the crown, the position of the incisal edge, the labial convexity of the crown, the color and translucency of the crown, the position of the labial margin of the peri-implant mucosa, the position of the mucosa in the interproximal embrasures, the contour of the labial surface of the mucosa, as well as the color and surface of the labial mucosa. All three indices have been applied in numerous studies and are well accepted for assessing esthetic outcomes (7, 18, 29, 47, 63, 72).

Esthetics as a patient-reported outcome measure: the judgment of the patient

Reports on patients' perception of implant treatment have gained considerable interest in recent years. This evolution seems logical, taking into account that

Fig. 1. (A) Preoperative view, central incisor 11 to be extracted because of root fracture. (B) Tooth 11 extracted. Ridge preservation and margo gingivae de-epithelialized. (C) Ridge preservation: xenogeneic bone substitute material placed in extraction socket. (D) Ridge preservation: autogenous free gingival graft placed on top of the extraction socket. (E) Digital implant planning 6 months following ridge preservation. (F) Dental implant placement using a digitally designed and printed surgical guide. (G) Contour augmentation using a xenogeneic bone substitute material on the buccal side of the implant. (H) Final reconstructions: all-ceramic crown (tooth 21); directly veneered zirconia abutment for screw-retained reconstruction (MDT; Pascal Müller, Zürich, Switzerland). (I) Final view (implant 11, crown 21). (J) Final X-ray. (K) Three-year follow up: clinical view. (L) Three-year follow up: X-ray.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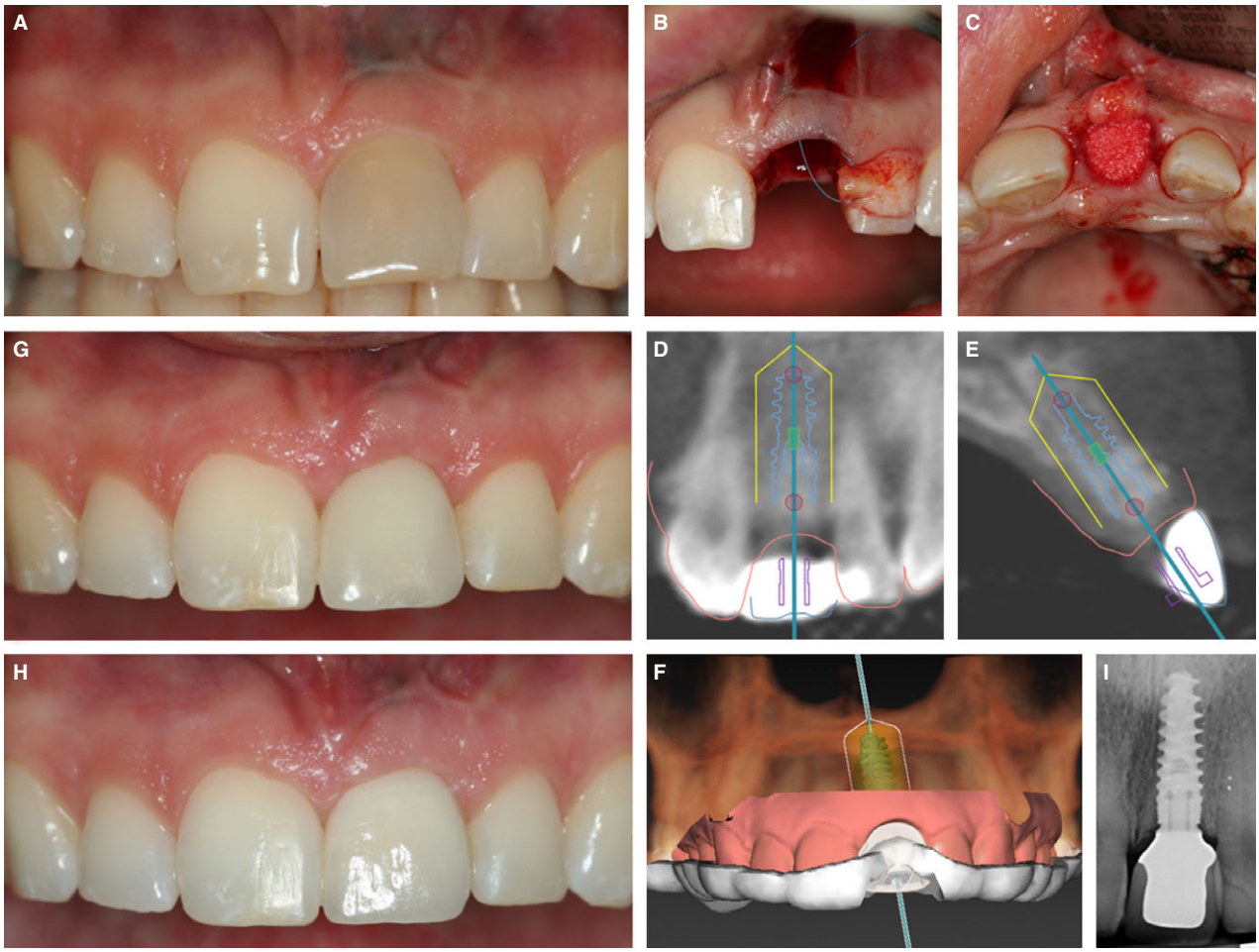

Fig. 2. (A) Preoperative view of failing tooth 21. (B, C) Tooth extraction and ridge preservation with connective tissue graft and bovine-derived xenograft. (D, E) Three-dimensional planning using NobelClinician software (NobelBiocare, Gothenburg, Sweden) for fabrication of the surgical guide. (F) Surgical pilot drill guide. (G) Slightly undersized provisional restoration following a 3-month osseointegration period. (H) Permanent restoration. (I) Intraoral radiograph of rehabilitation.

patients need to function with a prosthesis. Thus, their final evaluation should be considered pivotal, even if such assessment is subjective and therefore difficult to quantify.

Several terms have been used in the literature to express patients' perception of implant treatment, such as patient satisfaction, patient-centered outcomes and patient-reported outcomes. In the 8th European Workshop on Periodontology, the term 'patient-reported outcome measures' was introduced (43, 45). These essentially include 'subjective' reports of patients' perceptions of their oral health status and its impact on their daily life or quality of life (i), reports of satisfaction with oral health status and/or oral health care (ii) and other nonclinical assessments (iii) (43).

Esthetics is an important patient-reported outcomes measure and can be assessed in many ways. Nonstandardized questions are frequently used for this purpose, with varying scoring methods, including visual analog scales, Likert and other category scales and open questions (17). Although the information that comes from such nonstandardized questions may be valuable from an exploratory point of view, the validity and reliability of this '*ad-hoc*' approach may be questionable. As a result, it may be difficult, if not impossible, to compare studies on the basis of such questions. Validated questionnaires that have been used in implant dentistry are the Oral Health Impact Profile (the OHIP-49 with 49 standardized questions and the OHIP-14 with 14 standardized questions) (58) and Oral Health-Related Quality of Life (71). Both have been developed to assess the impact of oral health on the overall well-being of individuals and include some questions relating to esthetic aspects. In a recent report, it was proposed to use existing generic health patient-reported outcome measures (such as the Oral Health-Related Quality of

Life questionnaire) as a framework to develop standardized implant-specific patient-reported outcome measures (43).

A systematic review has recently been published on the use of patient-reported outcome measures in implant dentistry (17). Apart from the heterogeneity in reporting, a number of factors have been identified that could introduce a certain bias into the conclusions reached from patient-reported outcome measures. For one thing, it does not seem clear in many studies if patients actively sought implant treatment, if they were dissatisfied with their existing prostheses or if they paid for the treatment. In addition, patients were asked to evaluate treatment under varying conditions. Ideally, this should be performed in the absence of the clinician, yet such information is rarely described and may have been violated in a number of studies. As a result of all these factors, the true esthetic appreciation of patients has probably, to date, been overestimated.

Patients in need of a single anterior implant may be more critical than fully edentulous patients because of proportionally higher costs and esthetic concerns. Apart from that, it should be stressed that surgical and technological advancements may increase patients' expectations. This especially applies to modern implantology and the treatment of partially edentulous patients, which has increasingly become esthetically driven. Indeed, ridge preservation, connective tissue grafts, three-dimensional implant planning, guided surgery, provisional restorations and computer-aided design/computer-aided manufacturing technology are frequently used for anterior rehabilitations (13, 14, 16, 33, 68). All these advancements substantially increase patients' costs, making them even more critical from an esthetic point of view than they already are. Figures 1 and 2 show clinical examples of patients, with high esthetic demands, who are in need of an anterior rehabilitation. Future studies should continue to evaluate patient-reported outcome measures by using a standardized approach and focusing on partially edentulous patients. According to a recent systematic review, abundant data are available on fully edentulous patients treated with a mandibular implant overdenture. However, all other types of prostheses have been underexposed to research (17).

Objective versus subjective assessment of esthetics

In a number of clinical studies mainly relating to single tooth implants, objective esthetic scores have been compared with subjective esthetic scores. Already in 1999, 41 single implant restorations in 29 patients had been esthetically evaluated by prosthodontists and by patients (8). It was concluded that clinicians were more critical than patients in judging esthetics. Furthermore, factors considered by professionals to be of significance for the esthetic outcome appeared not to be of decisive importance for patients' satisfaction.

More recent studies, with data on larger patient samples, confirmed these findings. Meijndert et al. (47) evaluated 93 patients who had been treated with bone augmentation and a single implant. Clinicians were less satisfied than patients with respect to the esthetic outcome. In addition, both professionals and patients rated the soft-tissue outcome as less satisfactory than the implant crown. The authors could not find a correlation between the Implant Crown Aesthetic Index and the results of patient questionnaires. Cosyn et al. (13) evaluated the outcome of 104 single tooth implants after, on average, 2.5 years of function. A weak correlation between the pink esthetic score and patient's esthetic appraisal of the peri-implant mucosa was found. The same applied to the correlation between the white esthetic score and patient's esthetic appraisal of the implant crown. Esposito et al. (25) compared clinicians' and patients' judgment of esthetics on the basis of 30 pre- and postoperative pictures. The overall agreement between patients and clinicians, and also among clinicians, was poor (25). Interestingly, it has been described that the dentist's specialization may have a significant impact on the intra- and interobserver agreement of the pink esthetic score (28, 30). In this respect, orthodontists, of all specialists in dentistry, seem to be those most critical and reproducible in assessing esthetics.

Conclusions

Implant and superstructure survival, marginal bone loss and complications are important parameters for assessing the outcome of implant treatment. However, esthetics has become a key issue in contemporary practice and therefore esthetic evaluations should be included in clinical research. Clinicians, as well as patients, can judge the esthetic outcome of therapy in a number of ways. Although all may be valuable from an exploratory point of view, the heterogeneity in scoring systems between studies may compromise proper comparison of esthetic outcomes between studies and therapeutic concepts.

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