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The peri-implant mucosa color: A systematic appraisal of methods for its assessment and clinical significance

Running head: The peri-implant mucosa color

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ABSTRACT

Background. Peri-implant mucosa color (PMC) seems to be one of the main parameters affecting the esthetic outcome of implant therapy. However, more emphasis should be given to its assessment and reporting.

Purpose. To describe the available evidence on methods to assess and report the color of the peri-implant mucosa (PMC) and the respective clinical relevance.

Material and methods. A comprehensive electronic and manual search was performed to identify clinical studies reporting on PMC.

Results. One-hundred and twenty-one studies were included. PMC was evaluated at the time of the follow-up visit (chairside) in 45.5% studies. PMC assessment was performed qualitatively, by comparing PMC with adjacent and/or contralateral gingiva (78.6%) or quantitatively, using spectrophotometry (20.7%) or a software on clinical photographs (0.8%). The most performed method to assess PMC was through esthetic indices (76.9%), either at the time of the follow-up visit (chairside) or at later time point using photographs. Quantitative reporting of PMC included averages of points from esthetic indices or color differences to natural gingiva expressed with the CIELAB color system. PMC assessment allowed describing color discrepancies compared to natural gingiva, evaluating color changes over time, and comparing the outcomes of different treatment modalities. PMC assessment through spectrophotometry was additionally utilized to assess the role of mucosal thickness on PMC.

Conclusions. Various methods for PMC assessment and reporting were described, including visual assessment, mainly through esthetic indices, and spectrophotometry. PMC evaluation has allowed to demonstrate the factors affecting the color of the peri-implant soft tissue, such as the type of abutment/restoration, mucosal thickness, and soft tissue augmentation.

Key words: Dental implants, color, soft tissue, esthetics, systematic review, spectrophotometry

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STUDY DESIGN

The present study was design as a systematic review

SUMMARY BOX

What is known

- Peri-implant mucosa color is one of the main parameters affecting the esthetic outcome of implant therapy.
- Several methods for assessing and reporting peri-implant mucosa color have been described in the literature

What this study adds

- The present review describes the available evidence on methods to assess and report the color of the peri-implant mucosa and the respective clinical relevance.
- Objective methods for assessing peri-implant mucosa color mainly involve the use of spectrophotometry or professional esthetic indices.
- The type and color of the abutment, the type of restoration, soft tissue augmentation and peri-implant mucosal thickness, affect peri-implant mucosa color.
- The use of professional indices allows to assess the color match of the peri-implant mucosa with the adjacent soft tissue and/or gingiva of the contralateral tooth and to evaluate the stability of peri-implant mucosa color over time.

EQUATOR checklist: PRISMA Guidelines for improving reporting of systematic reviews.

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Introduction

Implant therapy has had a significant evolution over the years [1]. Advances in research, implant systems, techniques and biomaterials have contributed to increase the predictability and outcomes of dental implants [1-3]. From a patient's perspective, one of the most crucial parameters in implant therapy is the esthetics, with the appearance of the implant-supported crown and the peri-implant soft tissue that needs to mimic the ones of the natural dentition [4,5]. The esthetic outcomes of implant therapy depend on several factors. Severe bony and soft tissue dehiscences prior to implant placement are considered challenging clinical conditions for obtaining an ideal esthetic result [6]. It has been demonstrated that the esthetics of dental implants is often suboptimal, with an average incidence of peri-implant soft tissue dehiscence (PSTD) – defined as the apical shift of the peri-implant soft tissue margin compared to the cemento-enamel junction (CEJ) of the homologous contralateral tooth – of 54.2% and 56.8% on a patient and implant level, respectively [7]. Limited mucosal thickness, reduced/lack keratinized mucosa and buccal bone dehiscence were among the factors associated with this condition [7]. It has also been suggested that immediate implant therapy may increase the risk of esthetic complications [8,9].

On the other hand, the esthetics of dental implants depends also on the characteristics of the peri-implant mucosa in terms of keratinization, thickness, texture and color [10-12]. A study by Bonino and coworkers demonstrated a statistically significant association between patient-reported esthetic satisfaction following implant therapy and the presence of a band of keratinized mucosa [13]. The thickness of peri-implant mucosa has also been found to play a key role on the implant esthetic outcomes, with thin tissue often displaying greyish discoloration due to the implant components underneath [10,14,15].

Although peri-implant mucosa color (PMC) seems to be one of the main parameters affecting the esthetic outcome of implant therapy, little emphasis has been given on its assessment. PMC has often been reported as "similar" or "different" in comparison with the adjacent or contralateral natural gingiva and incorporated in esthetic indices with different scores [16-18]. Moreover, several authors have advocated the use of spectrophotometry to quantify color differences between peri-implant mucosa and the gingival of the adjacent or contralateral tooth [19-22], showing high accuracy and reproducibility for this technology [22-25].

In this scenario, guidelines for assessing and reporting PMC in clinical research are missing.

Therefore, the aim of the present manuscript was to describe the available evidence on methods utilized for assessing and reporting PMC and the respective clinical relevance.

2. Material and methods

2.1 Protocol Registration and Reporting Format

The protocol for the present review was designed according to the Cochrane guidelines [26] and reported with the Preferred Reporting Items for Systematic reviews and Meta-Analysis Extension (PRISMA)[27] statement for systematic reviews incorporating network meta-analyses for health care interventions.[28,29] The study protocol was registered and allocated the identification number CRD42021264941 in the PROSPERO database, hosted by the National Institute for Health Research, University of York, Center for Reviews and Dissemination (www.crd.york.ac.uk/PROSPERO).

2.2 Objectives

The goal of this review was to address the following focused question: What are the methods described for assessing and reporting PMC-related parameters and what is their clinical significance?

2.3 PICOT question

The following Population, Intervention, Comparison, Outcomes, and Time (PICOT) framework [30] was used to guide the inclusion and exclusion of studies for the above-mentioned focused questions:

Population (P): Patients with dental implants or in need of dental implant therapy

Intervention (I): Implant-related intervention (e.g., immediate or delayed implant placement, hard or soft tissue augmentation at implant sites, prosthetic restoration of dental implants, etc.) or visits in which PMC was assessed.

Comparison (C): Any comparison among the included studies in terms of the methods for evaluating PMC and their reliability assessment was evaluated.

Outcome (O): The current methods for assessing PMC, including direct comparison with adjacent or contralateral sites, professional indices/score systems and spectrophotometry were evaluated.

Time (T): No time restrictions were applied.

2.4. Inclusion Criteria

- Human studies
- Randomized clinical trial (RCT), prospective non-randomized trials and observational studies with at least 5 subjects
- Quantitative or qualitative assessment of PMC

2.5 Exclusion Criteria

- Reviews, case reports, retrospective, in-vitro or animal studies

- Studies with less than 5 subjects
- Studies providing the final score of an esthetic index involving the assessment of PMC, without reporting actual data on PMC
- Studies assessing the color of the implant-supported restoration only

2.6 Outcome measures

Any quantitative outcomes describing PMC was assessed.

Details on the search strategy, study selection, data extraction and risk of bias assessment are reported in the Supplementary Appendix.

3. Results

3.1 Search results and study selection

The literature search process is shown in Figure 1. Following removal of duplicates, 865 records were screened on the basis of titles and abstracts. Full-text assessment was performed for 327 articles. Based on the predetermined inclusion criteria, 121 articles were included [14-20,23,24,31-142]. The reason for exclusion of the other 196 articles is available in the Appendix (Supplementary Table 1). The inter-reviewer reliability in the screening and inclusion process, assessed with Cohen's κ, corresponded to 0.87 and 0.94 for assessment of titles and abstracts and full-text evaluation, respectively.

3.2 Characteristics of the included studies

Fifty-three studies were RCTs, 9 non RCTs, 32 case series and 27 observational studies (Supplementary Table 2 of the Appendix). Among the RCTs, 44 were conducted with a parallel arm design, 8 were split-mouth and 1 trial was a combination of a parallel group and a split-mouth study design. Overall, ninety-five studies were performed in a single center, while the remaining 26 were multicenter studies. One hundred studies were conducted at university, 15 in private practice and 6 in both university and private practice settings. Eighty-five studies were performed in Europe, 13 in Asia, 9 in North America, 6 in Europe and North America, 3 in Asia and North America, 2 in Africa, 2 in Oceania and 1 in South America. Smokers were excluded in 14 studies. Fifty articles included smokers based on the number of cigarettes consumed per day and 18 studies included smokers without any restrictions. The remaining 39 studies did not report this information. No funding from companies were reported in 96 studies, while the remaining 25 studies were funded by companies. Detailed study characteristics are described in the Supplementary Table 2 of the Appendix.

Ninety-three studies assessed the outcomes of bone level implants, six study the outcomes of tissue level implants, 1 article investigated both bone level and tissue level implants, and the remaining 21 studies did not report information on the implant type (Supplementary Table 3 of the Appendix).

Among the interventional studies, 37 articles evaluated the outcomes of immediate implant placement, 17 conventional implant placement, 14 implant placement followed by different abutments, 8 implant placement with guided bone regeneration, 9 peri-implant soft tissue augmentation with different graft materials, 3 flapless implant placement, 9 implant placement followed by different restoration material or protocol, 2 treatment of peri-implant soft tissue dehiscence and one study assessed the outcomes following second stage performed either with scalpel or laser (Supplementary Table 3 of the Appendix).

3.3 Methods for assessing PMC

PMC was evaluated either in person, at the time of the visit (direct assessment, chairside) (45.5% of the included studies) or after the appointment on the collected photographs (indirect assessment) (54.5% of the included studies). The direct evaluation of PMC was conducted either with spectrophotometry (20.7% of the included studies) or visual comparison with adjacent and/or contralateral natural gingiva (24.8% of the included studies).

PMC assessment was performed qualitatively or quantitatively. The qualitative evaluation involves the definition of PMC as equal or different from the color of the adjacent and/or contralateral natural gingiva. This method was employed in two articles (1.7%) [102,131]. Another qualitative evaluation is based on the visual observation of PMC that is then graded using esthetic score systems (qualitative PMC evaluation and quantitative PMC reporting). Ninety-three studies (76.9%) described PMC using esthetic indices with predetermined grading scores [16-18,31-36,38,39,42-48,50-67,70-77,80-82,84-93,95-101,103,104,106-113,115-123,125,128,129,134-137,140-142].

PMC was assessed quantitatively using spectrophotometry in twenty-five studies (20.7%) [14,15,19,20,23,24,37,40,41,49,68,78,79,83,87,94,105,114,124,126,127,130,132,133,139]. The outcomes of this evaluation utilized the CIELAB parameters (Commission Internationale de l'Eclaire; L= lightness, a= chroma along red-green axis, b= chroma along yellow-blue axis), in terms of ΔE, ΔL, Δa and Δb, for describing color differences in comparison with the adjacent and/or contralateral gingiva. One study (0.8%) utilized a software to import clinical photographs and to measure the lightness, green-red and blue-yellow shades of PMC, that were then converted to CIELAB color system [138]. Figure 2 summarizes the modalities for PMC assessment and reporting described in the included studies.

3.3.1 PMC assessment using esthetic indices

The Pink esthetic score (PES) [16] was utilized in 58 studies (62.4% of the studies assessing PMC with an index) [16,17,34-36,47,50-55,57-67,70-72,75,77,80,82,84,85,95,97-101,106,108-113,115-117,119-123,125,128,129,134,135], while the combined

pink and white esthetic score (PES/WES) [143] was employed in 26 articles (28.0%) [17,32,38,39,42-46,48,56,73,74,81,91-93,103,104,107,118,136,137,140-142]. Other esthetic indices utilized include the Copenhagen index score (CIS) [86-89], the Implant crown esthetic index (ICAI) [17,76], the Complex esthetic index (CEI) [17,33,96], the Implant aesthetic score (IAS) [17], the Implant restoration esthetic index (IREI) [101], the Mucosal scarring index (MSI) [55,144] and the Implant soft tissue dehiscence coverage esthetic score (IDES) [18]. One study utilized a modified gingival index [31], one article followed a 3-point scoring system (0 for obvious color differences, 1 for moderate difference and 2 for a natural color/no differences) [69] and one study mentioned a 0-2 point grading for PMC, without specifying the criteria for this evaluation [90] (Tables 1 and 2).

The assessment of PMC in these above-mentioned esthetic indices was described in detail in the Supplementary Appendix, and illustrated in Figure 3.

3.3.2 Significance of PMC assessment with esthetic indices

In 14 studies, the evaluation of PMC - as a parameter of the PES - provided information related to the color match with the gingiva of the reference tooth, without additional comparisons [16,17,51,53,71,77,84,85,95,99-101,108,109]. PMC assessment as a part of the PES evaluation was also utilized for assessing changes/stability of the color of peri-implant soft tissue over time in 15 studies [34,35,50,70,72,80,97,98,110-113,115,116,119], while the majority (N=29) of the articles reporting PMC from the PES evaluation utilized this parameter for comparing different treatment groups or interventions (e.g. immediate vs delayed implants, different implant systems, implants restored with different type of abutment, etc.) [36,47,52,54,55,57-67,75,82,106,117,120-123,125,128,129,134,135]. Similarly, 10 studies reporting PMC as a parameter of the PES/WES, provided information on color discrepancy with contralateral reference tooth only, without additional comparisons [17,32,38,39,42,44,48,56,91,118]. PMC as a part of the PES/WES assessment was utilized to evaluate color changes over time in 7 studies [43,46,81,103,104,107,140] and to compare color differences among different groups in 9 studies [45,73,74,92,93,137,141,142,144]. The other esthetic indices were mainly used for assessing PMC compared to adjacent gingiva/ gingiva of the contralateral tooth [18,76,86,96,101] or for evaluating the outcomes of different treatment protocols on the color of the peri-implant mucosa [33,55,87-89,144].

It can be summarized that the assessment of PMC as a component of esthetic indices has allowed: i) to describe the color match/discrepancy in relation to adjacent and/or contralateral natural gingiva, ii) to evaluate color changes of the same implant site at different time points and iii) to compare the effects of different treatments on the esthetic outcomes of dental implants.

3.3.3 PMC assessment using spectrophotometry

The characteristics of the twenty-five studies evaluating PMC with spectrophotometry are depicted in Table 3 and in the Supplementary Appendix. Some heterogeneity in the definition of the region of interest (ROI)

for the use of the spectrophotometer was observed. The outcomes of the spectrophotometric analysis were expressed as ΔE, ΔL, Δa and Δb, using the CIELAB parameters (Supplementary Table 4 of the Appendix). Five studies were designed to compare peri-implant and periodontal soft tissue color as primary outcomes, while the other studies focused on PMC with different abutments, restorations or interventions, incorporating the assessment of the gingival color at adjacent or contralateral sites as a secondary endpoint. In particular, fifteen studies utilized spectrophotometry for evaluating the effects of different abutments on PMC, four articles reported the PMC of implants with different necks, one study investigated the correlations between PMC and peri-implant mucosa characteristics, one trial assessed differences in PMC at sites that received connective tissue graft versus non-augmented sites and one RCT evaluated PMC at implant sites augmented with connective tissue graft or acellular dermal matrix (Table 3 and Supplementary Table 4 of the Appendix).

The use of spectrophotometer allowed demonstrating that the color of the peri-implant mucosa significantly differ from the color of the natural gingiva in 17 studies [14,20,23,24,37,40,41,49,68,79,105,114,124,130,132,133,139]. Through spectrophotometric analysis, 4 studies were able to conclude that zirconia abutments induce a different, and less marked, color change in peri-implant mucosa than titanium abutments as compared to natural gingiva [14,40,49,133], while two studies did not confirm this finding [41,68]. Anodized pink abutment had a significant different PMC than grey abutment according to Gil et al. 2017 [78]. Another study from the same group showed that implants with pink neck and abutment had similar PMC than natural gingiva [79]. This finding was confirmed also by Bittner and coworker using spectrophotometry [37]. Two studies showed that different restorations can result in different PMC [15,114]. Similarly, the use of spectrophotometer allowed to conclude that other factors, including veneering or not zirconia abutments or augmenting peri-implant soft tissue with connective tissue graft, can also play a role on PMC [87,126]. According to Hosseini, a better color match between peri-implant mucosa and natural gingiva was observed for implant sites augmented with connective tissue graft that also tended to maintain this color match over time, while non-augmented implant sites showed an increase color mismatch over the years compared to natural gingiva [87] (Supplementary Table 5 of the Appendix).

3.3.4 Influence of Mucosal thickness on PMC assessed with spectrophotometry

Twelve studies investigated possible correlations between mucosal thickness (MT) and PMC using spectrophotometry [14,23,40,41,49,68,87,94,105,124,126,127]. While three trials did not find a correlation between MT and PMC [40,41,87], nine studies demonstrated that MT has a significant impact on PMC [14,23,49,68,94,105,124,126,127]. Benic and coworkers observed an inverse correlation between MT and PMC, in terms of ΔE (total color difference) [23]. A similar conclusion was also reached by Jun et al. [94]. Two studies observed that the type of abutment significantly affected PMC only when MT was ≤ 2 mm [14,68]. According to Lops, gold and

zirconium abutments showed better PMC outcomes than titanium abutment in presence of MT ≤ 2 mm [14]. Similarly, Martinz-Rus and coworkers reported a correlation between MT and PMC for titanium and pink-anodized titanium abutments only [105], while Sailer and coworkers observed that MT had a significant impact on PMC at sites restored with zirconia and not titanium abutments [124]. Two studies from Thoma and coworkers further showed that MT has an impact on discoloration of the peri-implant soft tissue, although this association was not explored statistically, but it was obtained from sub-analyses dividing the sites in in MT < 2 and MT ≥ 2 [126,127] (Supplementary Table 5 of the Appendix).

3.3.5 Significance of PMC assessment with spectrophotometry

Quantitative assessment of PMC using spectrophotometry has allowed: i) to compare the esthetic outcomes of different abutments, restorations, or interventions, ii) to compare the color of natural gingiva of adjacent or contralateral dentition to PMC following different treatment protocols and iii) to investigate the effect of mucosal thickness on PMC.

3.4 Risk of bias assessment

The risk of bias is reported in detail in the Supplementary Tables 6-9 of the Appendix.

4. Discussion

The esthetic outcome of dental implants remains one of the most widely discussed topics in implant therapy, with patients and clinicians having the common goal of rehabilitating the edentulous site(s) with an implant-supported restoration unnoticeable from natural dentition [5,145-147].

It has been largely discussed that the esthetics of dental implants depend on several parameters, including but not limited to the position, thickness and appearance of the soft tissue phenotypes[16,148,149], the presence/height of the papillae [96,150,151] and the color, shape and texture of the implant-supported crown [5,143].

Although a great deal of interest has been centered on PMC, there are no currently guidelines on the methods recommended for its assessment and reporting in clinical research.

In the present manuscript we conducted a systematic appraisal of method for PMC assessment. Overall, PMC is frequently investigated in clinical studies, however its outcome is often not reported.

Among the 121 included articles, PMC assessment was more often performed after the research visit utilizing clinical photographs (54.5% of the studies). The evaluation of PMC in the remaining studies occurred during the research appointment (chairside) (45.5%), either with a visual examination (24.8%) or with a spectrophotometer (20.7%). While there are no studies comparing direct vs indirect PMC evaluation within the same patient population, one may speculate that the timing of the examination can affect the esthetic outcomes. The use of clinical photographs for esthetic assessment has several advantages compared

to direct examination, including high resolution of anatomical structures, the possibility of obtaining evaluations from several operators with different background/expertise and also comparing the esthetic outcomes at different time points. Therefore, it's not surprising that several esthetic indices that are nowadays routinely used have been proposed and validated with clinical photographs [16,18,144].

Nevertheless, standardization of clinical photographs presents several challenges. While certain aspects of dental photography, mainly related to equipment, setting, patient position and operator, can be standardized and reproduced, there are several non-standardizable factors related to the hardware of the camera, such as resolution, color space, bit depth, absolute color rendition, etc. that are device dependent[152]. The illumination is also a factor that can affect the color of photographs even if taken with the same camera. Future studies are needed to compare the outcomes of direct vs indirect PMC assessment.

In terms of outcome measure, PMC was mostly reported as a number (98.4%), either as an average score from the points assigned to each case according to the utilized esthetic index (76.9%) or as mean color difference (ΔE, ΔL, Δa and Δb according to the CIELAB system) with the adjacent and/or contralateral gingiva (21.5%). There are no doubts that grading PMC within predetermined esthetic indices is an easier, inexpensive, and less time-consuming method compared to spectrophotometry. Many esthetic indices - such as the PES, the PES/WES, the ICAI and the MSI [16,144,153,154] - utilize a three-point scale to rate PMC, based on obvious, moderate or lack of color mismatch between peri-implant mucosa and adjacent and/or contralateral gingiva. This simplicity in defining PMC may also represent a limit for the detection of less marked color differences among two investigated sites. In addition, the use of several indices with heterogenous criteria and scores for PMC often prevent the comparison of the esthetic outcomes among different studies in the literature.

On the other hand, spectrophotometry is the only currently available tool able to assess PMC in a quantitative manner. Intraoral scanners may represent an alternative – and more feasible – option to spectrophotometry to quantify PMC, however, more studies are needed to establish their accuracy in color reproduction [155,156]. Intraoral digital scanning appears to be a relatively easy and fast method for PMC assessment, but it has also to be considered that the calculation of PMC from the obtained digital models would require a certain level of experience with specific imaging software. Future studies in this direction are therefore advocated. On the other hand, spectrophotometry has been shown to be able to capture color differences that are not perceived by the human eye [22,24,157]. In the studies included in the present review, the use of spectrophotometry allowed to evaluate PMC following different abutments, restorations, and interventions, and also to investigate the effect of MT on the appearance of the peri-implant mucosa. Overall, there is evidence that PMC differs from the color of natural gingiva, which is probably due to the structural differences within the soft tissue in terms of cellularity, fiber orientation and vascularity, together with other factors related to the site (peri-implant soft tissue phenotype) and implant position [158,159].

However, by using spectrophotometry to assess PMC can reduce these color differences between peri-implant mucosa and the adjacent/contralateral gingiva. Hence, spectrophotometry may be a good tool for assessing PMC especially when it was used to compare the color of natural gingiva.

Dental implants with zirconia abutments tend to have less discoloration than titanium abutments [14,40,49,133] and that veneering zirconia abutments can further reduce color mismatch with contralateral gingiva [126]. Soft tissue augmentation at implant sites seems also to positively affect color match with adjacent and contralateral sites and the maintenance of this outcome over time [87], which is probably due to the increased MT that can prevent discoloration of the soft tissue from underlying implant components [11,14,160]. Most of the included studies investigating a correlation between PMC and MT using spectrophotometry concluded that MT has a significant impact on the color of peri-implant mucosa [14,23,49,68,94,105,124,126,127]. Current recommendations for improving esthetic outcomes of implant therapy advocate a MT of at least 2 mm for avoiding discoloration of the peri-implant mucosa [11,12,161].

Lastly, it should be mentioned that the literature has shown an inconsistent correlation between professional and patient esthetic evaluation [5,24,145,162]. The impact of PMC on patient-reported esthetic evaluation should be further evaluated.

5. Recommendation for future studies and proposal of new guidelines for evaluating PMC

Based on the present systematic appraisal, the following guidelines are suggested for evaluating and reporting PMC in clinical trials in dental implantology:

1. PMC evaluation should include the use of a spectrophotometer performed at different time points by a pre-calibrated operator: the color of the mucosa should be compared both with adjacent and contralateral gingiva and the result from these comparisons could be expressed using the CIELAB color system (ΔE, ΔL, Δa and Δb). Methods for standardizing PMC assessment with spectrophotometry, including determination of the region of interest and use of stents for reproducing the same position of the device at different time points, required further investigation.
2. PMC evaluation should also include the use of two or more professional esthetic indices (PES, PES/WES, ICAI, IAS, CIS, CEI, IREI and MSI) performed at different time points by a pre-calibrated operator: if the study involves treatment of peri-implant soft tissue dehiscences, using the IDES is advocated.

   Direct qualitative evaluation of PMC at the time of the appointment should be preferred over indirect assessment of PMC from photographs.
3. Patient-reported subjective assessment of PMC using a visual analogue scale should also be reported: this outcome should be compared with professional evaluation of PMC (spectrophotometry and esthetic indices).

4. Intraoral digital scanners can be used to assess of PMC and soft tissue texture and shape.

Future studies should take into consideration these recommendations for assessing PMC to improve reproducibility of PMC assessment and comparison of PMC outcomes among different studies and treatment modalities. The accuracy of intraoral digital scanners for PMC and esthetic assessment needs to be explored in future research.

6. Conclusions

Based on the currently available evidence, and the limitations within this research, the following conclusions can be drawn:

1. The color of peri-implant mucosa is often investigated in clinical studies as one of the main esthetic outcomes.
2. Objective methods for assessing PMC mainly involve the use of spectrophotometry (quantitative assessment using the CIELAB color system) or professional esthetic indices (qualitative assessment).
3. Spectrophotometric assessment of PMC demonstrated that the color of the soft tissue around dental implants and natural teeth often differs. Several factors, including the type and color of the abutment, the type of restoration, soft tissue augmentation and peri-implant mucosal thickness, were found to affect PMC and to have the potential of promoting a better color match between peri-implant mucosa and natural gingiva.
4. There is evidence that mucosal thickness is correlated to PMC, with thin mucosa (< 2 mm) showing greater chance of discoloration compared to the natural gingiva of adjacent or contralateral teeth.
5. Several professional indices introduced for assessing the esthetic outcomes of dental implants (PES, PES/WES, ICAI, IAS, CIS, CEI, IREI, MSI and IDES) involves the evaluation of PMC, which is rated based on the color match with the adjacent soft tissue and/or gingiva of the contralateral homologous tooth. The use of these indices also allows to evaluate the stability of PMC over time and to compare different intervention/treatment protocols in terms of final PMC.
6. The high level of heterogeneity observed between the included studies assessing PMC, in terms of study design, methods for PMC assessment, and reported outcomes, render comparisons among different studies and protocols challenging at the present time.

Conflict of interest

The authors do not have any financial interests, either directly or indirectly, in the products or information enclosed in the paper. The study was self-supported.

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Figures and Tables Legend

Figure 1. PRISMA Flowchart

Figure 2. Summary of the modalities for assessing and reporting peri-implant mucosa color. The percentage of the included articles utilizing the different modalities are reported in gray.

Figure 3. Illustration of the professional esthetic indices involving the assessment of peri-implant mucosa color

Table 1. Characteristics of the studies assessing PMC with esthetic indices.

Table 2. Characteristics of PMC within the esthetic indices utilized in the included studies.

Table 3. Characteristics of intervention among the studies quantitatively evaluating PMC using spectrophotometry.

Figure 1. PRISMA flowchart.

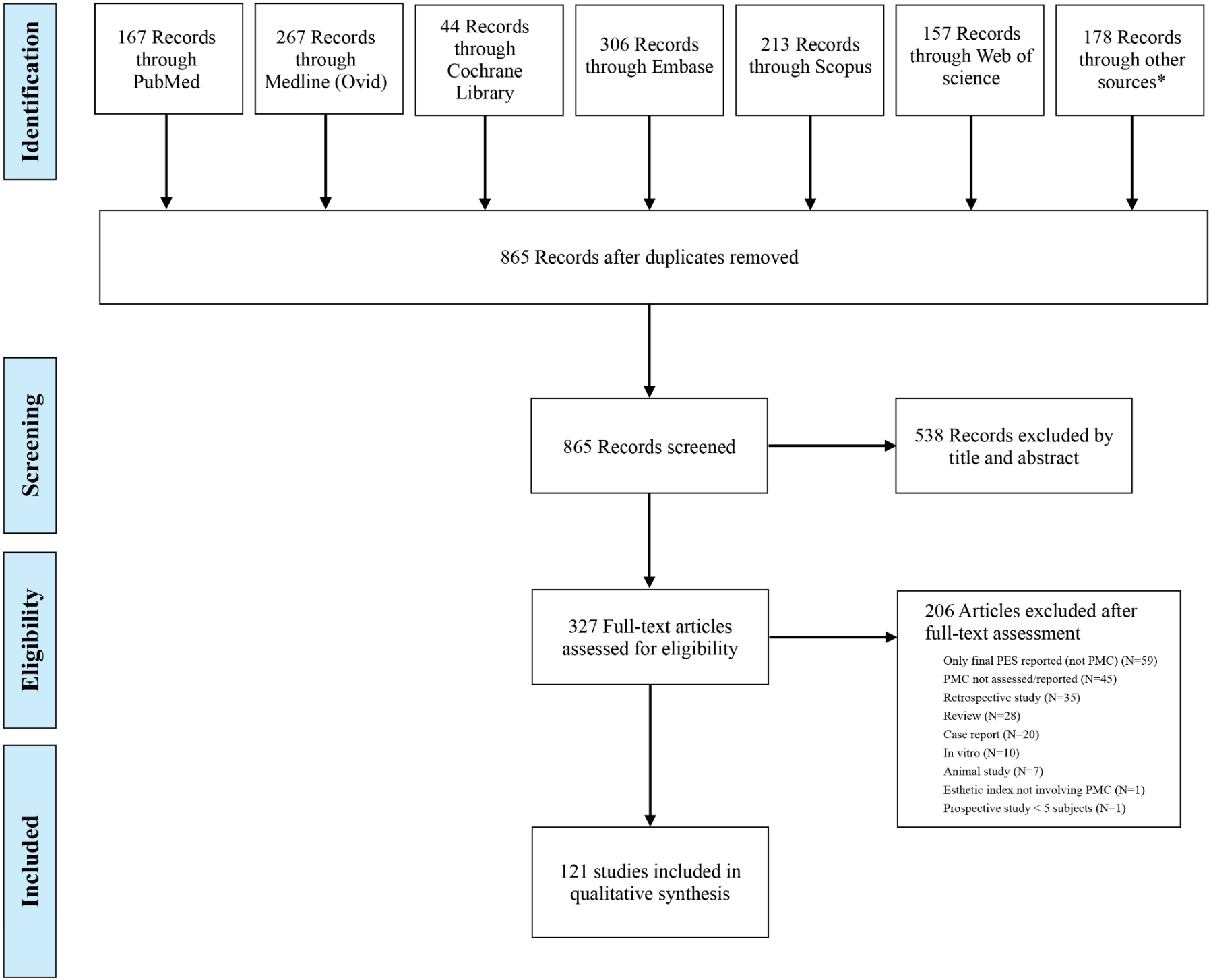


Figure 2. Summary of the modalities for assessing and reporting peri-implant mucosa color. The percentage of the included articles utilizing the different modalities are reported in gray.

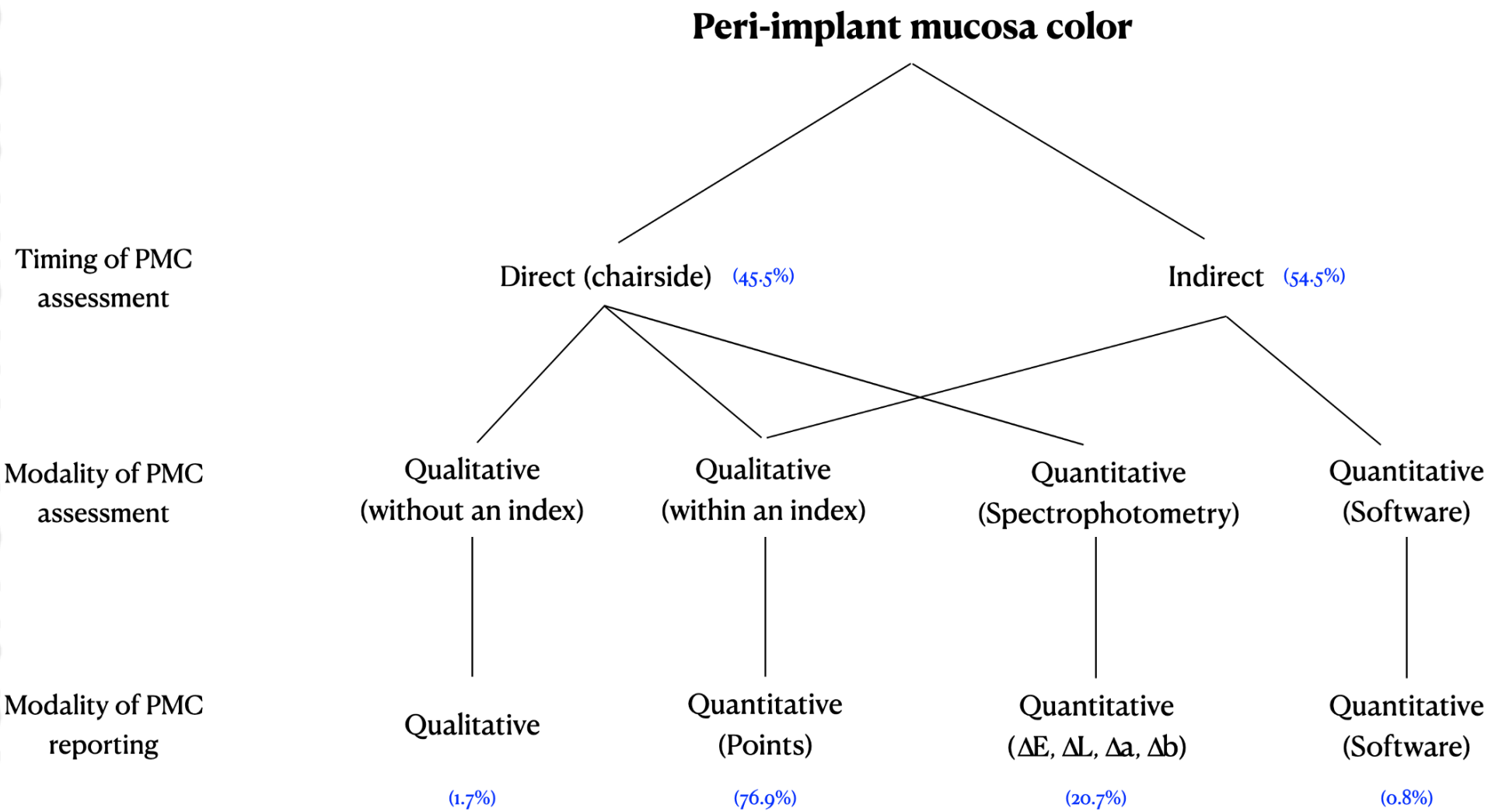
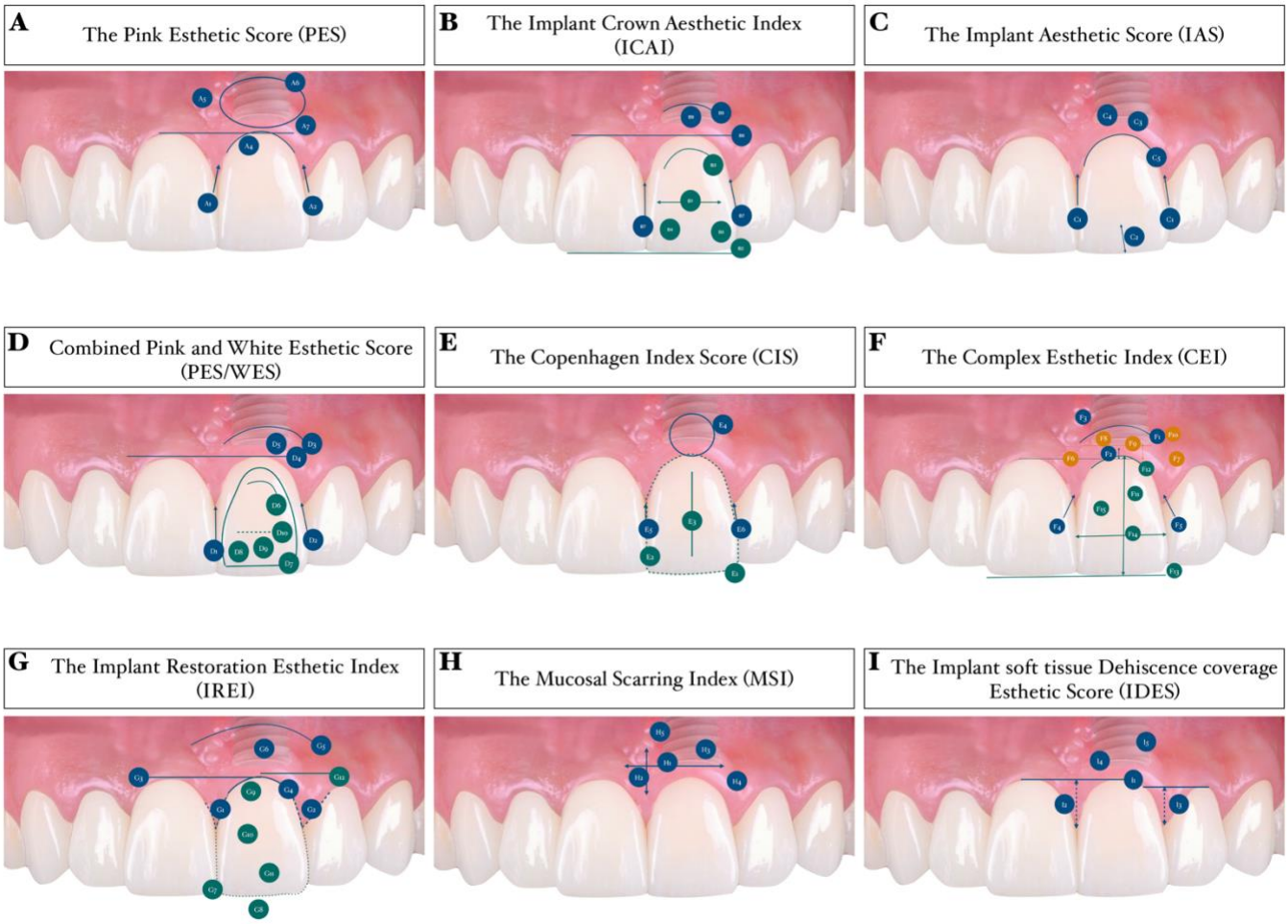


Figure 3. Illustration of the professional esthetic indices involving the assessment of peri-implant mucosa color.



Legend. A) The Pink Esthetic Score. A1) Mesial papilla shape/presence, A2) Distal papilla shape/presence, A3) Level of the soft tissue margin, A4) Soft tissue contour, A5) Alveolar process, A6) Soft tissue color, A7) Soft tissue texture. B) The Implant Crown Aesthetic Index (ICAI). B1) Mesio-distal dimension of the crown, B2) Position of the incised edge of the crown, B3) Labial convexity of the crown, B4) Color and translucency of the crown, B5) Surface of the crown, B6) Position of the labial margin of the peri-implant mucosa, B7) Position of the mucosa in the approximal embrasures, B8) Contour of the labial surface of the mucosa, B9) Color and surface of the labial mucosa. C) The Implant Aesthetic Score (IAS), C1) Presence and stability of the mesial and distal papilla, C2) Ridge stability buccopalatally, C3) Texture of the peri-implant soft tissue, C4) Color of the peri-implant soft tissue, C5) Gingival color. D) Combined Pink and White Esthetic Score (PES/WES). D1) Mesial papilla shape/presence, D2) Distal papilla shape/presence, D3) Curvature of the facial mucosa, D4) Level of the facial mucosa, D5) Root convexity/Soft tissue color and texture, D6) tooth form, D7) Outline/volume, D8) Color (hue/value), D9) Surface texture, D10) Translucency/Characterization. E) The Copenhagen Index Score (CIS). E1) Crown morphology, E2) Crown color match, E3) Symmetry/Harmony, E4) Mucosal discoloration, E5) Mesial papilla, E6) Distal papilla. F) The Complex Esthetic Index (CEI). F1) Soft tissue contour variations, F2) Soft tissue vertical deficiency, F3) Soft tissue color and texture variations, F4) Mesial papillae appearance, F5) distal papillae appearance, F6) Mesial interproximal bone height, F7) Distal interproximal bone height, F8) Gingival tissue biotype, F9) Implant apico-coronal position, F10) Horizontal contour deficiency, F11) Color and translucency, F12) Labial convexity in the abutment junction, F13) Implant crown incisal edge, F14) Crown width/length ratio, F15) Surface roughness and ridges. G) The Implant Restoration Esthetic Index (IREI). G1) Mesial papilla presence, G2) Distal papilla presence, G3) Gingival trigone, G4) Soft tissue curvature, G5) Alveolar process deficiency, G6) Soft tissue color and texture, G7) Crown contour, G8) Crown position, G9) Crown labial convexity, G10) Crown characterization, G11) Crown color and translucency, G12) Abutment visibility. H) The Mucosal Scarring Index (MSI). H1) Width of the scar, H2) Height/contour of the scar, H3) Color of the scar, H4) Visibility of the suture marks, H5) Overall appearance. I) The Implant soft tissue Dehiscence coverage Esthetic Score (IDES). I1) Soft tissue margin, I2) Peri-implant papillae height, I3) Peri-implant mucosa color, I4) Peri-implant mucosa appearance.

Table 1. Characteristics of the studies assessing PMC with esthetic indices.

Publication, reference	Investigated group(s)	PMC assessment	Photographic documentation (camera, lens, flash, settings)	Index/Indices	Multiple time points
(Al-Delayme, 2019)	Laser vs Scalpel	Direct	NR	Modified gingival index	1, 2 and 3 weeks
(Al-Dosari, Al-Rowis, Moslem, Alshehri, & Ballo, 2016)	Implants in the esthetic zone	Indirect	Nikon D5000,90mm micro f/2.8 Nikon lens, ring flash sigma EM-140	PES/WES	No
(Anderson et al., 2014)	Sites treated with CTG vs ADM	Direct	NR	CEI	BL, 6 weeks, 3 months and 6 months
(Arora & Ivanovski, 2017)	Immediate implants	Indirect	SLR camera Canon 1100D	PES	No
(Arora, Khzam, Roberts, Bruce, & Ivanovski, 2017)	Immediate implants	Indirect	SLR camera Canon 1300D	PES	No
(Atef, El Barbary, Dahrous, & Zahran, 2021)	Immediate implants (conventional approach vs socket shield)	Indirect	NR	PES	12 months
(Boon et al., 2020)	Implant sites	Direct	NR	PES/WES	6 and 12 months
(Borgonovo et al., 2013)	Zirconia implants	Direct	NR	PES/WES	No
(Buser et al., 2009)	Implant sites augmented with GBR	Indirect	NR	PES/WES	No
(Buser et al., 2011)	Implant sites augmented with GBR	Indirect	NR	PES/WES	12 and 36 months
(Canullo, Menini, Covani, & Pesce, 2020)	Implants with convergent collar	Indirect	Canon Rebel XT with 100mm macro lens and ring flash	PES/WES	No
(Cappare et al., 2021)	Immediate loading following digital vs traditional workflow	Direct	NR	PES/WES	12 months
(Chappuis et al., 2018)	Implant sites augmented with GBR	Indirect	NR	PES/WES	1, 3, 6 and 10 years
(Checchi et al., 2017)	Immediate implants	Indirect	Camera NR. Magnification of 1/4	PES	No

(Cho, Lee, Um, & Chang, 2010)	Implants in the esthetic zone	Indirect	Nikon D80, 105 micro-F/2.8G IF-ED; ring flash Sigma EM-140; Magnification 1X-2X	PES/WES	No
(Jan Cosyn et al., 2011)	Immediate implants	Direct	NR	PES	No
(J. Cosyn, Eghbali, De Bruyn, Dierens, & De Rouck, 2012)	Implants placed 6-8 weeks vs ≥ 6 months after extraction	Direct	NR	PES	No
(J. Cosyn, De Bruyn, & Cleymaet, 2013)	Immediate implants	Direct	NR	PES	No
(Cutrim, Peruzzo, & Benatti, 2012)	Implants in the esthetic zone	Indirect	Canon Powershot SD7901S	PES	No
(De Angelis et al., 2011)	Immediate implants	Indirect	Camera NR. Magnification of 1/4	PES	No
(De Bruyckere et al., 2020)	Implants + GBR vs CTG	Indirect	Nikon d300s with twin flash Nikon R1C1	MSI, PES	No
(den Hartog et al., 2013)	Implants with different neck designs	Indirect	Fuji-film FinePix S3 Pro	PES/WES	No
(Donos, Horvath, Calciolari, & Mardas, 2019)	Implants with or without immediate provisionalization	Direct	NR	PES	36, 48, 60 months
(Elaskary, Y, Maebed, Cho, & El Tantawi, 2020)	Immediate implants	Direct	NR	PES	6 and 13 months
(Esposito et al., 2015)	Immediate vs delayed implant placement	Indirect	Camera NR. Magnification of 1/4	PES	4 and 12 months
(Esposito et al., 2016)	Immediate implants	Indirect	Camera NR. Magnification of 1/4	PES	No
(Esposito, Bressan, et al., 2017)	Implant placement (multiple abutments removal vs no removal)	Indirect	NR	PES	4 and 12 months
(Esposito, Tallarico, Trullenque-Eriksson, & Gianserra, 2017)	Immediate implant vs endodontic retreatment	Indirect	NR	PES	Completion of the treatment and 1 year later
(Esposito, Zucchelli, et al., 2017)	Immediate vs delayed implant placement	Indirect	Camera NR. Magnification of 1/4	PES	4 and 12 months
(Esposito, Cardaropoli, et al., 2018)	Implant placement with different abutment designs	Indirect	NR	PES	No

(Esposito, González-García, et al., 2018)	Immediate implants placed at different positions	Indirect	Camera NR. Magnification of 1/4	PES	No
(Felice, Pistilli, Barausse, Trullenque-Eriksson, & Esposito, 2015)	Immediate vs delayed implant placement	Indirect	Camera NR. Magnification of 1/4	PES	4 and 12 months
(Felice et al., 2016)	Immediate vs delayed implant placement	Indirect	Camera NR. Magnification of 1/4	PES	No
(Froum et al., 2015)	XCM vs non-augmented sites	Direct	NR	3-point scoring system introduced by the Authors	No
(Fügl et al., 2017)	Anodized tapered implants with conical connection and platform switching	Direct	NR	PES	6 and 12 months
(Furhauser et al., 2005)	Single implants	Indirect	Digital camera D100 Nikon; ring flash Nikon	PES	No
(Fürhauser et al., 2015)	Flapless implants	Indirect	Canon EOS 5D MK III; 100mm f1:28 macro; ring flash Canon	PES	No
(Fürhauser et al., 2017)	Immediate implants	Indirect	Canon EOS 5D MK III; Macro Lens 100 mm 1:2.8; Macro Ring Lite MR-14EX	PES	6, 12 and 60 months
(Furze et al., 2019)	Implants with or without provisional phase	Direct	NR	PES/WES	No
(Gallucci, Grütter, Nedir, Bischof, & Belser, 2011)	Implants with different restorations	Indirect	Camera NR. Magnification of 1:1	PES/WES	No
(Garcia-Sanchez, Mardas, Buti, Ortiz Ruiz, & Pardo Zamora, 2021)	Immediate implants with two different flap approaches	Indirect	NR	PES	12 months
(Gehrke, Lobert, & Dhom, 2008)	Single implants	Indirect	NR	PES	No
(Gehrke, Degidi, Lulay-Saad, & Dhom, 2009)	Single implants	Indirect	NR	ICAI	No
(Groenendijk, Staas, Bronkhorst,	Immediate implants	Indirect	NR	PES	2 weeks, at abutment

Raghoebar, & Meijer, 2020)					connection and 12 months
(Gu et al., 2015)	Single implants	Indirect	Nikon D70	PES/WES	1 and 2 years
(Gualini et al., 2017)	Implants placed 0.5 mm or 1.5 mm subcrestally	Indirect	NR	PES	2 and 12 months
(Hartlev et al., 2014)	Immediate implants with immediate provisionalization	Indirect	Canon EOS 10D, lens EF 100 mm, MR-14EX ring flash, 1:2.8 USM macro lens	PES	No
(Hof et al., 2013)	Single implants following bone grafting	Indirect	NR	PES	No
(Hof et al., 2018)	Single implants	Indirect	Digital camera with 100mm macro lens, ring flash	CEI, IAS, ICAI, PES, PES/WES	No
(Hosseini, Worsaae, Schiodt, & Gotfredsen, 2011)	Implant placement with different restorations	Indirect	NR	CIS	No
(Hosseini & Gotfredsen, 2012)	Single implants	Indirect	NR	CIS	No
(Hosseini, Worsaae, Schiodt, & Gotfredsen, 2013)	Implant placement with different restorations	Indirect	NR	CIS	No
(Hosseini, Worsaae, & Gotfredsen, 2020)	Implants + CTG vs non-augmented implant sites	Direct	NR	CIS	No
(Huang et al., 2021)	FGG vs XCM	Direct	NR	0-2 score	No
(Jones & Martin, 2014)	Single implants	Indirect	NR	PES/WES	No
(Jonker, Wolvius, van der Tas, & Pijpe, 2019)	Implants + GBR (with or without membrane)	Indirect	Canon 5D, 100m F2.8 macro lens	PES/WES	1, 6 and 12 months
(Jonker, Wolvius, van der Tas, Tahmaseb, & Pijpe, 2020)	Implants + GBR vs implants in native bone	Indirect	NR	PES/WES	1, 6 and 12 months
(Juodzbalys & Wang, 2007)	Immediate implants	Direct	NR	PES	No
(Juodzbalys & Wang, 2010)	Implants in the esthetic zone	Direct	NR	CEI	No
(Kolinski et al., 2018)	Immediate implants	Direct	NR	PES	Delivery of the prosthesis and 12 months

(Konstantinidis, Siormpas, Kontsiotou-Siormpa, Mitsias, & Kotsakis, 2016)	Implants that received roll flap technique	Indirect	Digital camera with ring flash	PES	Baseline and 10 years
(Kunavisarut, Buranajanyakul, Kitisubkanchana, & Pumpaluk, 2020)	One-piece ceramic implants	Indirect	NR	PES	1 week and 1 year
(Lai et al., 2008)	Single implants	Indirect	Nikon D70	PES	Baseline and 6-8 months
(Li et al., 2019)	Single implants	Direct	NR	IREI, PES	No
(Lorenzo, Garcia, Orsini, Martin, & Sanz, 2012)	Soft tissue augmentation with FGG vs XCM	Indirect	NR	(No index, color match only)	No
(Mangano et al., 2014)	Single implants	Indirect	Nikon D100R, 105mm lens, 1:2.8 magnification, ring flash	PES/WES	3 months and 3 years
(Marconcini et al., 2018)	Implants in preserved vs non-preserved sites	Indirect	Canon 1300D	PES/WES	Baseline, 1, 2, 3 and 4 years
(Mau et al., 2019)	Implants + GBR with xenogeneic vs allogeneic bone graft	Direct	NR	PES	No
(Meijndert, Raghoebar, Santing, Vissink, & Meijer, 2020)	Single implants	Direct	NR	PES/WES	No
(Nissen & Starch-Jensen, 2019)	Implants following sinus augmentation	Direct	NR	PES	No
(Noelken, Kunkel, & Wagner, 2011)	Immediate implants	Direct	NR	PES	No
(Noelken, Neffe, Kunkel, & Wagner, 2014)	Immediate implants	Direct	NR	PES	1 and 2 years
(Noelken, Oberhansl, Kunkel, & Wagner, 2016)	Immediate implants	Direct	NR	PES	No
(Noelken, Moergel, Kunkel, & Wagner, 2018)	Immediate implants	Direct	NR	PES	No
(Östman, Chu, Drago, Saito, & Nevins, 2020)	Immediate implants	Direct	NR	PES	6, 12 and 24 months

(Pieri, Aldini, Marchetti, & Corinaldesi, 2013)	Implants following bone augmentation	Indirect	Fuji S2, Pro	PES	Crown delivery and 5 years
(Pieri, Siroli, Forlivesi, & Corinaldesi, 2014)	Single implants	Direct	NR	PES	Baseline and 3 years
(Pohl, Cede, Pokorny, Haas, & Pohl, 2022)	Immediate implants (augmented with bovine collagen vs non-augmented)	Indirect	Canon EOS-1 DX	PES	Baseline, 1, 3 and 12 months
(Pollini, Morton, Arunyanak, Harris, & Lin, 2020)	Single implants	Indirect	Nikon D300	PES/WES	No
(Prati et al., 2020)	Flapless implants vs early vs delayed implants	Indirect	NR	PES	6, 12 and 36 months
(Puisys, Auzbikaviciute, et al., 2022)	Immediate vs early implants	Indirect	NR	PES	4-5 and 12 months
(Puisys, Deikuviene, et al., 2022)	Immediate implants (CTG vs ADM)	Indirect	NR	PES	4 and 12 months
(Raes, Cosyn, Crommelinck, Coessens, & De Bruyn, 2011)	Immediate vs delayed	Indirect	Digital camera, ring flash	PES	No
(Rieder et al., 2016)	Immediate vs early implants (and immediate vs early restoration)	Indirect	Nikon D90	PES	No
(Sun et al., 2020)	Flapless implants vs	Indirect	NR	PES	6 and 24 months
(Urban et al., 2019)	Implants + GBR with cross-linked vs non-cross-linked membranes	Indirect	NR	PES	No
(van Nimwegen et al., 2018)	Immediate implants (with or without CTG)	Indirect	Canon Eos 650, ring flash	PES	No
(Vellis et al., 2019)	Soft tissue augmentation with FGG vs XCM	Indirect	NR	(No index, color match only)	No
(Wanis, Hosny, & ElNahass, 2022)	Immediate implants	Direct	NR	PES	6 and 12 months

(Weinländer et al., 2011)	Implants with different abutment designs	Indirect	NR	PES	No
(Wessels, Vervaeke, Seyssens, Eghbali, & Cosyn, 2020)	Early implants + GBR vs ARP + CTG and delayed implants	Indirect	NR	MSI, PES/WES	No
(Wittneben et al., 2017)	Implants with different abutments	Direct	NR	PES/WES	6 and 12 months
(Zucchelli et al., 2021)	Implants with PSTDs	Indirect	Nikon D7200	IDES	Baseline and 1 week
(Zucchelli et al., 2018)	PSTDs treated with crown removal and CAF + CTG	Indirect	NR	PES/WES	Baseline, 1 and 5 years
(E. Zuiderveld, Meijer, Vissink, & Raghoebar, 2018)	Implants with CTG vs XCM vs non-augmented implants	Indirect	NR	PES/WES	No
(E. G. Zuiderveld, Meijer, Vissink, & Raghoebar, 2019)	Implants in preserved vs non-preserved sites	Indirect	Canon EOS 650D, ring flash	PES/WES	No

Legend. ADM: acellular dermal matrix; ARP: alveolar ridge preservation; CEI: Complex esthetic index; CIS: Copenhagen index score; CTG: connective tissue graft; FGG: free gingival graft; GBR: guided bone regeneration; IAS: Implant aesthetic index; ICAI: Implant crown esthetic index; IDES: Implant soft tissue dehiscence coverage esthetic score; IREI: Implant restoration esthetic index; MSI: mucosal scarring index; NR: not reported; PES: Pink esthetic score; PES/WES: combined pink and white esthetic score; PMC: peri-implant; PSTD: peri-implant soft tissue dehiscence; ROI: region of interest; XCM: xenogeneic collagen matrix

Table 2. Characteristics of PMC within the esthetic indices utilized in the included studies.

Index	Is PMC assessed as an individual parameter?	Reference for PMC	Categories for PMC (points)	Maximum score for the index (points)
PES (Furhauser et al., 2005)	Yes	Gingiva of the contralateral tooth	Obvious difference (0) Moderate difference (1) No difference (Giannobile, Jung, Schwarz, & Groups of the 2nd Osteology Foundation Consensus)	14
ICAI (Meijer, Stellingsma, Meijndert, & Raghoebar, 2005)	No (together with the surface of the mucosa)	Gingiva of the contralateral tooth	Gross mismatch (1) Slight mismatch (Giannobile et al.) No mismatch (3)	35
IAS (Testori et al., 2005)	Yes	Healthy gingiva	Completely different (0) Not similar but acceptable (1) Similar (Giannobile et al.)	9
PES/WES (Belser et al., 2009)	No (together with root convexity and soft tissue texture)	Gingiva of the contralateral tooth	Major discrepancy (0) Minor discrepancy (1) No discrepancy (Giannobile et al.)	20
CIS (Dueled, Gotfredsen, Trab Damsgaard, & Hede, 2009)	Yes	Adjacent soft tissue	No visible discoloration (1) Light greyish discoloration (Giannobile et al.) Distinct greyish discoloration (3) Discoloration with visible metal (4)	24
CEI (Juodzbalys & Wang, 2010)	No (together with soft tissue texture)	Adjacent soft tissue	Deficient (0*) Compromised (10*) Adequate (20*)	100*
IREI (Li et al., 2019)	No (together with soft tissue texture)	Gingiva of the adjacent and contralateral tooth	No categories, PMC assessed using a VAS	100
MSI (Wessels et al., 2019)	Yes	Gingiva of the adjacent and contralateral tooth	Perfect color match (0) Slight mismatch (1) Obvious mismatch (Giannobile et al.)	10
IDES (Zucchelli et al., 2021)	Yes	Adjacent soft tissue	Distinguishable from adjacent soft tissue (0) Not distinguishable from adjacent soft tissue (0)	10

Legend. CEI: Complex esthetic index; CIS: Copenhagen index score; IAS: Implant aesthetic index; ICAI: Implant crown esthetic index; IDES: Implant soft tissue dehiscence coverage esthetic score; IREI: Implant restoration esthetic index; MSI: mucosal scarring index; PES: Pink esthetic score; PES/WES: combined pink and white esthetic score.
*: refers to a percentage and not to points.

Table 3. Characteristics of intervention among the studies quantitatively evaluating PMC using spectrophotometry.

Publication, reference	Study comparison	Treatment group	Specifics of the spectrophotometer	Landmarks for the ROI	PMC outcomes	Multiple follow-up visits
(Benic, Scherrer, Sancho-Puchades, Thoma, & Hämmerle, 2017)	PMC vs color of gingiva in natural dentition	All ceramic Metal-ceramic Metal	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	Circular area of 1 mm Ø (1 mm apical to the mid-buccal mucosal/gingival margin)	ΔE ΔL Δa Δb	No
(Bittner et al., 2020)	PMC of implants with different necks	Pink neck Grey abutments	Crystaleye®, Olympus	3 incremental areas (1x1 mm) from the gingival margin in the apical direction (cervical, middle, apical)	ΔE ΔL Δa Δb	3 weeks and 6 months
(Bressan et al., 2011)	PMC with different abutments and comparison with color of gingiva in natural dentition	**Abutments** Titanium Gold-alloy Zirconia	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	5 mm area around the gingival margin of the implant and contralateral tooth	ΔE ΔL Δa Δb	No
(Büchi, Sailer, Fehmer, Hämmerle, & Thoma, 2014)	PMC with different abutments	**Abutments** Pink zirconia Zirconia	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	1 mm below the gingival margin of the implant and contralateral tooth	ΔE ΔL Δa Δb	BL, 5 min, 10 min and 1 week
(Cosgarea et al., 2015)	PMC with different abutments	**Abutments** Titanium Zirconia	Shade vision system, X-Rite Inc.	1 mm^2 located on the buccal gingival aspect of the abutments/ crowns/tooth at 1 mm, 2 mm, 3 mm from the gingival margin	ΔE ΔL Δa Δb	20 min and 1 week
(Ferrari, Carrabba, Vichi, Goracci, & Cagidiaco, 2017)	PMC with different abutments	**Abutments** Titanium Titanium nitride Zirconia	VITA easy shade	1 mm below the gingival margin of the implant and contralateral tooth	ΔE ΔL Δa Δb	No

(Gil et al., 2017)	PMC with different abutments and implants with different necks	**Abutments** Grey implant and grey abutment, Grey implant and Pink abutment, Pink implant and grey abutment, Pink implant and Pink abutment	Crystaleye®, (Olympus Co., Tokyo, Japan)	3 incremental areas (1x1 mm) from the gingival margin in the apical direction (cervical, middle, apical) of implant and contralateral tooth	ΔL Δa Δb	No
(Gil et al., 2019)	PMC with different abutments and implants with different necks	Pink neck Grey abutments Pink abutments	Crystaleye®, (Olympus Co., Tokyo, Japan)	3 incremental areas (1x1 mm) from the gingival margin in the apical direction (cervical, middle, apical) of implant and contralateral tooth	ΔL Δa Δb	2 and 3 weeks
(Happe, Schmidt, & Neugebauer, 2022)	PMC of immediate implant augmented with different soft tissue grafts	Acellular dermal matrix vs Connective tissue graft	SpectroShade, Type 71.3000, MHT Optic Research AG, Switzerland	Not reported	ΔE	12 months
(Hosseini, Worsaae, & Gotfredsen, 2020)	PMC of augmented vs non-augmented implants	Connective tissue graft vs non-augmented sites	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	Circular area of 3 mm Ø on the marginal implant mucosa and of the adjacent tooth	ΔE ΔL Δa Δb	BL, 1, 3, and 5 years
(Ishikawa-Nagai, Da Silva, Weber, & Park, 2007)	PMC of implants with different necks	Colour strips White Black Light pink Pink Light orange Orange Gold violet	Handy-MSC, (Olympus Co., Tokyo, Japan)	Circular area of 20 mm Ø on the marginal implant mucosa and of adjacent or contralateral tooth	ΔL Δa Δb	BL and 5 min
(Jun et al., 2013)	PMC with different abutments	**Abutments** Black White	Shadepilot,Degudent	5mm^2 area around the gingival margin	ΔL Δa Δb	No
(Jung et al., 2008)	PMC of implants with different restorations	Ceramic on Al_2O_3 abutments Fused to metal (PFM) with titanium or gold abutment	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	Circular area of 3 mm Ø on the marginal implant mucosa and of the adjacent tooth	ΔE ΔL Δa Δb	BL, 1 and 2 weeks

(Lops et al., 2017)	PMC with different abutments	**Abutments** Titanium Gold-alloy Zirconia	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	1mm below the gingival margin 4mm^2 area around the implant mucosa and adjacent tooth	ΔE ΔL Δa Δb	No
(Martínez-Rus et al., 2017)	PMC with different abutments	**Abutments** Pink anodized Titanium Gold anodized titanium Zirconia dioxide	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	1mm below the gingival margin Circular area of 3 mm Ø around the implant mucosa and adjacent tooth	ΔE	No
(Paniz, Bressan, Stellini, Romeo, & Lops, 2014)	PMC vs color of gingiva in natural dentition	Esthetic evaluation	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	5mm^2 area around the gingival margin of implant mucosa and adjacent tooth	ΔE ΔL Δa Δb	No
(Park, Da Silva, Weber, & Ishikawa-Nagai, 2007)	PMC vs color of gingiva in natural dentition	Implant tooth	Handy-MSC, (Olympus Co., Tokyo, Japan)	Circular area of 20 mm Ø (five incremental areas in 1mm increments) on the marginal implant mucosa and of adjacent or contralateral tooth	ΔE ΔL Δa Δb	No
(Peng et al., 2017)	PMC with different abutments	**Abutments** Titanium, Gold-gold with zirconia coping, Titanium with metal coping, Titanium with gold-gold hue and metal coping, Zirconia	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	Circular area of 3 mm Ø on the marginal implant mucosa and of adjacent or contralateral tooth	ΔE ΔL Δa Δb	No
(Sailer et al., 2009)	PMC with different abutments	**Abutments** Titanium, Customized zirconia	Spectroshade™ Micro Device; Medical High Technologies, Verona, Italy	1mm below the gingival margin Circular area of 3 mm Ø around the implant mucosa and contralateral tooth	ΔE ΔL Δa Δb	BL, 6 and 12 months
(Thoma et al., 2016)	PMC with different abutments	**Abutments** White zirconia, Pink-veneered zirconia	Spectroshade, MHT Optic Research AG, Niederhasli, Switzerland	1mm below the gingival margin around the implant mucosa and contralateral tooth	ΔE ΔL Δa Δb	BL, 5 and 10 min

(Thoma et al., 2017)	PMC with different abutments	**Abutments** Fluorescent Zirconia, Zirconia	Spectroshade, MHT Optic Research AG, Niederhasli, Switzerland	1mm below the gingival margin around the implant mucosa and adjacent tooth	ΔE ΔL Δa Δb	BL, abutment try-in, final crown
(Varoni et al., 2017)	PMC vs color of gingiva in natural dentition	Implant tooth	Portable UV-Vis-NIR spectrophotometer (HR4000; Ocean Optics, Dunedin, FL) Fiber optics reflectance spectroscopy with a 45°x:45° geometry	1mm below the gingival margin Circular area of 2,25 mm Ø around the implant mucosa and contralateral tooth (three incremental areas in 2 mm increments)	ΔE ΔL Δa Δb	No
(Waller et al., 2020)	PMC vs color of gingiva in natural dentition	Esthetic evaluation	Spectroshade, MHT Optic Research AG, Niederhasli, Switzerland	1mm below the gingival margin Circular area of 5 mm Ø around the implant mucosa and contralateral tooth	ΔE	No
(Wang, Wang, Lu, & Fan, 2020)	PMC with different abutments	**Abutments** Gold titanium Pink titanium Titanium zirconia	Crystaleye®, (Olympus Co., Tokyo, Japan)	Are of $4mm^2$ around the implant mucosa and contralateral tooth	ΔE ΔL Δa Δb	No
(Zembic, Sailer, Jung, & Hammerle, 2009)	PMC with different abutments	**Abutments** Titanium zirconia	Spectroshade, MHT Optic Research AG, Niederhasli, Switzerland	1mm below the gingival margin Circular area of 3 mm Ø around the implant mucosa and contralateral tooth	ΔE ΔL Δa Δb	No

Legend. BL: baseline. PMC: peri-implant. ROI: region of interest. Δa: color difference on the red/green axis according to the CIELAB (Commission Internationale de l'Eclaire) system. Δb: color difference on the yellow/blue axis according to the CIELAB system. ΔE: total color difference value according to the CIELAB system. ΔL: color difference in lightness/darkness according to the CIELAB system.