Supplementary Appendix

Volumetric changes at implant sites: a systematic appraisal of traditional methods and optical scanning-based digital technologies

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Information sources and Search Strategy

A detailed systematic literature search was conducted using the following electronic data bases: The National Library of Medicine (MEDLINE via PubMed); EMBASE via OVID; the Cochrane Central Register of Controlled Trials. For examining unpublished trials, the grey literature, nonprofit reports, government research or other materials, were also electronically explored through searching in ClinicalTrial.gov and OpenGrey (www.opengrey.eu). The search was conducted on March 23, 2020 and updated on October 2, 2020.

The search strategy was primarily designed for the MEDLINE database with a string of medical subject headings and free text terms, and then modified appropriately for other databases. No restrictions were set for date of publication, journal or language. The search results were downloaded to a bibliographic database to facilitate duplicate removal and cross-reference check.

To ensure a thorough screening process, the electronic search was complemented with a manual search Additionally, reference lists of the retrieved studies for full-text screening and previous reviews in the topic of immediate implants and peri-implant plastic surgery were screened (Bassetti et al., 2017, Bassetti et al., 2016, Cairo et al., 2008, Cairo et al., 2019, Gargallo-Albiol et al., 2019, Gobbato et al., 2013, Kinaia et al., 2017, Lee et al., 2016, Lin et al., 2013, Lin et al., 2018, Poskevicius et al., 2017, Rotundo et al., 2015, Suarez-Lopez Del Amo et al., 2016, Thoma et al., 2014b, Thoma et al., 2018, Thoma et al., 2014a, Tavelli et al., 2020a, Tavelli et al., 2020b, Wennstrom and Derks, 2012, Zucchelli et al., 2020).

Electronic database search keywords

MEDLINE:

("dental implant"[All Fields] AND "thickness"[All Fields]) OR ("dental implant"[All Fields] AND "volume"[All Fields]) OR ("dental implant"[All Fields] AND "scan"[All Fields]) OR ("dental implant"[All Fields] AND "volumetric"[All Fields]) OR ("dental implant"[All Fields] AND "optical"[All Fields]) OR ("dental implant"[All Fields] AND "dimensional"[All Fields])

EMBASE:

('dental implant'/exp OR 'dental implant') AND ('thickness'/exp OR 'thickness') OR (('dental implant'/exp OR 'dental implant') AND ('volume'/exp OR 'volume')) OR (('dental implant'/exp OR 'dental implant') AND 'scan') OR (('dental implant'/exp OR 'dental implant') AND 'volumetric') OR (('dental implant'/exp OR 'dental implant') AND ('optical'/exp OR 'optical')) OR (('dental implant'/exp OR 'dental implant') AND 'dimensional')

Cochrane:

('dental implant'/exp OR 'dental implant') AND ('thickness'/exp OR 'thickness') OR (('dental implant'/exp OR 'dental implant') AND ('volume'/exp OR 'volume')) OR (('dental implant'/exp OR 'dental implant') AND 'scan') OR (('dental implant'/exp OR 'dental implant') AND 'volumetric') OR (('dental implant'/exp

OR 'dental implant') AND ('optical'/exp OR 'optical')) OR (('dental implant'/exp OR 'dental implant') AND 'dimensional')

Web of Science:
TOPIC: ("dental implant" AND "thickness") *OR* **TOPIC:**("dental implant" AND "volume") *OR***TOPIC:** ("dental implant" AND "scan") *OR* **TOPIC:** ("dental implant" AND "volumetric") *OR* **TOPIC:**("dental implant" AND "optical") *OR***TOPIC:** ("dental implant" AND "dimensional")

The search strategy was primarily designed for the MEDLINE database with a string of medical subject headings and free text terms, and then modified appropriately for other databases. No restrictions were set for date of publication, journal or language. The search results were downloaded to a bibliographic database to facilitate duplicate removal and cross-reference checks.

To ensure a thorough screening process, the electronic search was complemented with a manual search in the following journals: *Journal of Dental Research, Journal of Clinical Periodontology, Journal of Periodontology, Clinical Oral Implants Research, Clinical Implant Dentistry and Related Research, The International Journal of Oral & Maxillofacial Implants, Journal of Oral and Maxillofacial Surgery, International Journal of Oral Implantology, Clinical Oral Investigations, and International Journal of Periodontics* and *Restorative Dentistry*. The manual search period was from January 1, 2000 to August 31, 2020.

Study Selection

Two calibrated examiners (LT and SB) screened the titles and abstracts (if available) of the entries identified in the search, in duplicate and independently. Next, the full text version of all studies that potentially met the eligibility criteria or for which there was insufficient information in the title and abstract to make a decision, were obtained. Any article considered as potentially relevant by at least one of the reviewers was included in the next screening phase. Subsequently, the full-text publications were also evaluated in duplicate and independently by the same review examiners. The examiners were calibrated with the first 10 full-text, consecutive publications. Any disagreement on the eligibility of the studies was resolved through open debate between both reviewers until an agreement was reached or through settlement by an arbiter (JM). All articles that did not meet the eligibility criteria were excluded and the reasons for exclusion were noted. Inter-examiner agreement following full-text assessment was calculated via kappa statistics. Disagreement on the inclusion of the studies at any point was resolved in the same manner as previously mentioned.

Quality assessment and risk of bias

The risk of bias at the study level was assessed independently and in duplicate by two authors (LT and SB). For randomized clinical trials (RCTs), it was performed according to the recommended approach by the Cochrane collaboration group (Higgins et al., 2011). For non-randomized cohort studies included in the qualitative analysis, the ROBINS-I tool (Sterne et al., 2016) was used to determine the potential risk of bias. For case series, the Joanna Briggs Institute Critical Appraisal tool (Moola et al., 2017) was utilized for quality assessment. Any disagreement was discussed between the same authors. Another author (JM) was consulted in case no agreement was reached. However, no study was excluded on the basis of the risk of bias within a study.

Criteria for assessment of risk of bias for the included studies

The recommendation of the Cochrane collaboration group for randomized trials (Higgins et al., 2011):

1. Random sequence generation. Selection bias (biased allocation to interventions) due to inadequate generation of a randomized sequence).
2. Allocation concealment. Selection bias (biased allocation to interventions) due to inadequate concealment of allocations prior to assignment.
3. Blinding of participants and personnel. Performance bias due to knowledge of the allocated interventions by participants and personnel during the study.
4. Blinding of outcome assessment. Detection bias due to knowledge of the allocated interventions by outcome assessors.
5. Incomplete outcome data addresses. Attrition bias due to amount, nature or handling of incomplete outcome data.
6. Selective reporting. Reporting bias due to selective outcome reporting.
7. Other bias. Bias due to problems not covered elsewhere in the table.

In summary, the potential risk of bias was categorized as low if a study provided detailed information on the above parameters. Moderate risk was considered if a study failed to provide information on only one of the parameters, whereas if a study showed missing information pertaining to >2 parameters, it was categorized as exhibiting a high risk of bias. At last, a trial was categorized as having an "unclear risk of bias" in case of missing or insufficient data to determine its risk and if we had no way to determine or obtain more information.

The ROBINS-I tool (Sterne et al., 2016) for non-randomized cohort studies:

1. Bias due to confounding
2. Bias in selection of participants
3. Bias in classification of intervention
4. Bias due to deviations from intended interventions
5. Bias due to missing data
6. Bias in measurement of outcomes
7. Bias in selection of the reported result

In summary, the potential risk of bias was categorized as low if a study provided detailed information on the above parameters. Low risk was considered if the study was judged to be at low risk of bias for all domains. Moderate risk was assigned when the study is considered to be at low or moderate risk of bias for all domains, whereas if a study was at serious risk of bias in at least one domain, but not at critical risk

of bias in any domain, it was categorized as exhibiting a serious risk of bias. Lastly, the study is judged to be at critical risk of bias if at least one domain was assigned as having a critical risk of bias.

The Joanna Briggs Institute Critical Appraisal tool (Moola et al., 2017) for assessment of case series:

1. Were there clear criteria for inclusion in the case series
2. Was the condition measured in a standard, reliable way for all participants?
3. Were valid methods used for identification of the condition for all participants?
4. Did the case series have consecutive inclusion of participants?
5. Did the case series have complete inclusion of participants?
6. Was there clear reporting of the demographics of the participants?
7. Was there clear reporting of clinical information of the participants?
8. Were the outcomes or follow-up results clearly reported?
9. Was there clear reporting of the presenting site (s)/clinic(s) demographic information
10. Was the statistical analysand appropriate?
11. Overall risk of bias

Low risk was considered if the study was judged to be at low risk of bias for all domains. Moderate risk was assigned when the study is considered to be at moderate/unclear risk of ≤ 2 domains, with all the other domains being at low risk of bias. A study was judged to be at high risk of bias if least one domain was assigned as having a high risk of bias or if >2 domains were considered to be at moderate/unclear risk of bias.

Supplementary Table 1: Reference and the reason for the excluded articles.

Reason for exclusion	Reference
Non-human studies (n=3)	(Barootchi et al., 2020, Chan et al., 2018, Sanz-Martin et al., 2018)
Non-interventional studies (n=6)	(Bohner et al., 2019, Chang and Wennström, 2013, Fuchigami et al., 2017, Salmon and Le Denmat, 2012, Schwarz et al., 2017, Wang et al., 2020a)
Retrospective studies (n=5)	(Amato et al., 2018, Baumer et al., 2017, Le et al., 2016, Levin et al., 2020, Speroni et al., 2010)
Data on guided bone regeneration prior to implant placement (n=1)	(Thoma et al., 2019)
Data on volumetric changes after alveolar ridge preservation only (n=1)	(Thoma et al., 2020a)
Soft tissue augmentation at edentulous sites (n=4)	(Akcali et al., 2015, Bienz et al., 2017, Gonzalez-Martin et al., 2014, Sanz-Martín et al., 2016)
Peri-implant mucosa variations not reported (n=60)	(Agrawal et al., 2017, Ahmed and Hassan, 2019, Andersen et al., 2001, Andersson et al., 2003, Arora and Ivanovski, 2017, Assaf et al., 2014, Barone et al., 2015, Benic et al., 2019, Bruschi et al., 2014a, Bruschi et al., 2014b, Buser et al., 2013a, Buser et al., 2013b, Caiazzo et al., 2018, Canullo et al., 2019, Cardaropoli et al., 2019, Cecchinato et al., 2015, Chen et al., 2019, Chu et al., 2018, Chu et al., 2020b, Crespi et al., 2019b, Crespi et al., 2019a, Demircan and Demircan, 2015, Di Stefano et al., 2020, Esposito et al., 2018, Farronato et al., 2020b, Felice et al., 2014, Fretwurst et al., 2015, Frisch et al., 2015, Guarnieri et al., 2016, Guarnieri et al., 2020, Hu et al., 2018, Jensen et al., 2014, Jiang et al., 2018, Kolinski et al., 2018, Liu et al., 2019, Malchiodi et al., 2013, Marconcini et al., 2018, Morimoto et al., 2015, Naeini et al., 2018, Noelken et al., 2018b, Noelken et al., 2014, Ortiz-Vigón et al., 2018, Östman et al., 2020, Raes et al., 2015, Raghoebar et al., 2009, Roccuzzo et al., 2019, Sanz et al., 2014, Sarnachiaro et al., 2016, Slagter et al., 2016, Spinato et al., 2019, Sun et al., 2020, Sunitha and Sapthagiri,

Peri-implant mucosa dimension assessed at a single time point (n=28)	2013, Tatum et al., 2020, Temmerman et al., 2020, Trombelli et al., 2020, Verdugo et al., 2020, Worni et al., 2018, Wu et al., 2019, Yoo et al., 2019, Zuffetti et al., 2013) (Bressan et al., 2011, Cabello et al., 2013, Chu et al., 2020a, Cosgarea et al., 2015, de Siqueira et al., 2017, de Siqueira et al., 2020, Farronato et al., 2020a, Ferrari et al., 2015, Glibert et al., 2018, Göthberg et al., 2018, Guarnieri et al., 2019a, Koutouzis et al., 2019, Lee et al., 2020, Levin and Chu, 2018, Linkevicius et al., 2018, Linkevicius et al., 2015b, Linkevicius et al., 2015c, Lops et al., 2015, Lops et al., 2017, Noelken et al., 2018a, Puisys and Linkevicius, 2015, Saito et al., 2018, Thoma et al., 2017, van Eekeren et al., 2017, Veltri et al., 2016, Vervaeke et al., 2014, Vervaeke et al., 2018, Wang et al., 2020b)

General characteristics of the included studies

Thirty-seven of the included studies were RCTs (Anderson et al., 2014, Bashutski et al., 2013, Basler et al., 2018, Bertl et al., 2017, Bittner et al., 2020, Cairo et al., 2017, Clementini et al., 2019, Clementini et al., 2020, D'Elia et al., 2017, De Bruyckere et al., 2020, De Bruyckere et al., 2018, Eisner et al., 2018, Farina and Zaffe, 2015, Farronato et al., 2020a, Frizzera et al., 2019, Froum et al., 2015, Fu et al., 2014, Huber et al., 2018, Hutton et al., 2018, Jiang et al., 2020, Migliorati et al., 2015, Papapetros et al., 2019, Poli et al., 2019, Puzio et al., 2018, Puzio et al., 2020, Rojo et al., 2018, Rojo et al., 2020, Sanz Martin et al., 2016, Sapata et al., 2018, Thoma et al., 2020b, Thoma et al., 2016, Ustaoğlu et al., 2020, van Nimwegen et al., 2018, Wang et al., 2019, Wiesner et al., 2010, Zafiropoulos et al., 2016, Zeltner et al., 2017), ten articles were prospective non-randomized comparative studies (Benic et al., 2017, Chu et al., 2020a, Hosseini et al., 2020, Kato et al., 2018, Ko et al., 2020, Linkevicius et al., 2015a, Rungcharassaeng et al., 2012, Saito et al., 2018, Torkzaban et al., 2015, Verardi et al., 2019) and the remaining thirty were case series (Andreasi Bassi et al., 2016, Borges et al., 2020, Cabanes-Gumbau et al., 2019, Canullo et al., 2018, Cardaropoli et al., 2006, Chappuis et al., 2018, De Bruyckere et al., 2015, Eeckhout et al., 2020, Eghbali et al., 2016, Eghbali et al., 2018, Fischer et al., 2019, Friberg and Jemt, 2012, Galarraga-Vinueza et al., 2020, Guarnieri et al., 2019b, Hanser and Khoury, 2016, Hinze et al., 2018, Kaminaka et al., 2015, Papi et al., 2019, Papi et al., 2020, Parvini et al., 2020, Puisys et al., 2015, Sanz-Martin et al., 2019, Schallhorn et al., 2015, Schneider et al., 2011, Stefanini et al., 2016, Stefanini et al., 2020, Tian et al., 2019, Wei et al., 2019, Wittneben et al., 2016, Zucchelli et al., 2018, Zucchelli et al., 2013).

General characteristics of studies using optical scanning-based digital technologies

Four studies (Huber et al., 2018, Rojo et al., 2020, Sapata et al., 2018, Thoma et al., 2020b) evaluated the three-dimensional (3D) volumetric outcomes on the same cohort of patients of previous published articles (Rojo et al., 2018, Sanz Martin et al., 2016, Zeltner et al., 2017) with a longer follow-up or a different analysis. Three studies were conducted in private practice (Canullo et al., 2018, Fischer et al., 2019, Hinze et al., 2018), one multicenter study in both private practice and university (De Bruyckere et al., 2020) while the rest had been performed in an academic setting.

Ten studies focused on volumetric changes following immediate implant placement (Bittner et al., 2020, Borges et al., 2020, Clementini et al., 2020, Hinze et al., 2018, Jiang et al., 2020, Sanz-Martin et al., 2019, Tian et al., 2019, van Nimwegen et al., 2018, Wang et al., 2019, Wei et al., 2019), four studies on volumetric outcomes after implant placement without hard or soft tissue augmentation (Benic et al., 2017, Hosseini et al., 2020, Sanz Martin et al., 2016, Sapata et al., 2018) and four articles on volumetric changes after implant placement and simultaneous guided bone regeneration (Basler et al., 2018, Benic et al., 2017, De Bruyckere et al., 2020, Schneider et al., 2011). Volumetric changes following peri-implant soft

tissue conditioning with abutments and provisional crowns were assessed in three studies (Cabanes-Gumbau et al., 2019, Canullo et al., 2018, Wittneben et al., 2016), while thirteen articles evaluated volumetric variations after soft tissue grafting (De Bruyckere et al., 2020, Eeckhout et al., 2020, Fischer et al., 2019, Friberg and Jemt, 2012, Hosseini et al., 2020, Huber et al., 2018, Papi et al., 2020, Parvini et al., 2020, Rojo et al., 2018, Rojo et al., 2020, Schneider et al., 2011, Thoma et al., 2020b, Zeltner et al., 2017) and one study investigated tissue changes following combined surgical therapy of peri-implantitis (Galarraga-Vinueza et al., 2020). Four studies had measured the mucosal thickness (MT) using an endodontic file with a silicon stop and a caliper (Hosseini et al., 2020, Huber et al., 2018, Papi et al., 2020, Thoma et al., 2020b); however, a correlation between the obtained transgingival probing and the 3D digital analysis was not explored (Table 1 of the main manuscript).

General characteristics of studies assessing peri-implant mucosal changes using transgingival piercing techniques

Thirty studies assessed peri-implant mucosa changes using transgingival piercing methods only (Anderson et al., 2014, Andreasi Bassi et al., 2016, Bashutski et al., 2013, Cairo et al., 2017, Clementini et al., 2019, D'Elia et al., 2017, Eisner et al., 2018, Farina and Zaffe, 2015, Froum et al., 2015, Fu et al., 2014, Guarnieri et al., 2019b, Hanser and Khoury, 2016, Hutton et al., 2018, Linkevicius et al., 2015a, Migliorati et al., 2015, Papapetros et al., 2019, Papi et al., 2019, Poli et al., 2019, Puisys et al., 2015, Schallhorn et al., 2015, Stefanini et al., 2016, Stefanini et al., 2020, Thoma et al., 2016, Torkzaban et al., 2015, Ustaoğlu et al., 2020, Verardi et al., 2019, Wiesner et al., 2010, Zafiropoulos et al., 2016, Zucchelli et al., 2018, Zucchelli et al., 2013). Four studies assessing 3D volumetric changes had also measured MT variation using an endodontic file with a silicon stop (Hosseini et al., 2020, Huber et al., 2018, Papi et al., 2020, Thoma et al., 2020b). Three studies (Huber et al., 2018, Thoma et al., 2020b, Zucchelli et al., 2018) evaluated the outcomes on the same cohort of patients of previous published articles (Thoma et al., 2016, Zucchelli et al., 2013) with a longer follow-up or a different analysis.

Among the thirty articles evaluating mucosal changes with transgingival piercing methods only, seventeen were randomized controlled trials (Anderson et al., 2014, Bashutski et al., 2013, Cairo et al., 2017, Clementini et al., 2019, D'Elia et al., 2017, Eisner et al., 2018, Farina and Zaffe, 2015, Froum et al., 2015, Fu et al., 2014, Hutton et al., 2018, Migliorati et al., 2015, Papapetros et al., 2019, Poli et al., 2019, Thoma et al., 2016, Ustaoğlu et al., 2020, Wiesner et al., 2010, Zafiropoulos et al., 2016), ten case series (Andreasi Bassi et al., 2016, Guarnieri et al., 2019b, Hanser and Khoury, 2016, Papi et al., 2019, Puisys et al., 2015, Schallhorn et al., 2015, Stefanini et al., 2016, Stefanini et al., 2020, Zucchelli et al., 2018, Zucchelli et al., 2013) and three non-randomized comparative studies (Linkevicius et al., 2015a, Torkzaban et al., 2015, Verardi et al., 2019).

Overall, peri-implant mucosa piercing was performed with endodontic instruments in twenty-one studies (Anderson et al., 2014, Andreasi Bassi et al., 2016, Bashutski et al., 2013, D'Elia et al., 2017, Eisner et al., 2018, Froum et al., 2015, Fu et al., 2014, Guarnieri et al., 2019b, Hosseini et al., 2020, Huber et al., 2018, Migliorati et al., 2015, Papi et al., 2019, Papi et al., 2020, Poli et al., 2019, Schallhorn et al., 2015, Thoma et al., 2016, Thoma et al., 2020b, Torkzaban et al., 2015, Ustaoğlu et al., 2020, Wiesner et al., 2010, Zafiropoulos et al., 2016), while injection needles (Cairo et al., 2017, Clementini et al., 2019, Stefanini et al., 2016, Stefanini et al., 2020, Zucchelli et al., 2018, Zucchelli et al., 2013) and periodontal probe (Farina and Zaffe, 2015, Hanser and Khoury, 2016, Hutton et al., 2018, Linkevicius et al., 2015a, Papapetros et al., 2019, Puisys et al., 2015, Verardi et al., 2019) were used in six and seven articles, respectively (Supplementary Table 4). Silicon or rubber disk stop were used in the included studies using endodontic instruments or injection needles, while among the seven articles utilizing periodontal probes, only two of them reported the use of silicon disk stops (Hutton et al., 2018, Papapetros et al., 2019). Supracrestal tissue height (STH) changes were the main soft tissue-related outcome in four studies (Farina and Zaffe, 2015, Linkevicius et al., 2015a, Puisys et al., 2015, Verardi et al., 2019), while STH was assessed together with buccal MT in three articles (Papapetros et al., 2019, Thoma et al., 2016, Ustaoğlu et al., 2020); the other studies evaluated MT gain only (Anderson et al., 2014, Andreasi Bassi et al., 2016, Bashutski et al., 2013, Cairo et al., 2017, Clementini et al., 2019, D'Elia et al., 2017, Eisner et al., 2018, Froum et al., 2015, Fu et al., 2014, Guarnieri et al., 2019b, Hanser and Khoury, 2016, Hosseini et al., 2020, Huber et al., 2018, Hutton et al., 2018, Migliorati et al., 2015, Papi et al., 2019, Poli et al., 2019, Schallhorn et al., 2015, Stefanini et al., 2016, Stefanini et al., 2020, Thoma et al., 2020b, Torkzaban et al., 2015, Wiesner et al., 2010, Zafiropoulos et al., 2016, Zucchelli et al., 2018, Zucchelli et al., 2013). Thirteen articles reported the use of a digital caliper for assessing the obtained distance between the tip of the instruments used and the silicon/rubber disk stop (Cairo et al., 2017, Clementini et al., 2019, Hosseini et al., 2020, Papapetros et al., 2019, Papi et al., 2019, Papi et al., 2020, Poli et al., 2019, Stefanini et al., 2016, Stefanini et al., 2020, Torkzaban et al., 2015, Ustaoğlu et al., 2020, Zucchelli et al., 2018, Zucchelli et al., 2013). The accuracy of the digital caliper was reported to be 0.01 mm in two studies (Cairo et al., 2017, Papi et al., 2019) and 0.1 mm in seven articles (Clementini et al., 2019, Hosseini et al., 2020, Papi et al., 2020, Stefanini et al., 2016, Stefanini et al., 2020, Zucchelli et al., 2018, Zucchelli et al., 2013), while the remaining four studies did not report this information (Papapetros et al., 2019, Poli et al., 2019, Torkzaban et al., 2015, Ustaoğlu et al., 2020). A large heterogeneity was observed among the articles using transgingival probing techniques in terms of reference points for measuring MT (Supplementary Table 8). The most utilized landmarks are 1 mm coronal to the mucogingival junction, 1 mm and/or 3 mm and/or 5 mm apical to the soft tissue margin (Anderson et al., 2014, Andreasi Bassi et al., 2016, Clementini et al., 2019, Eisner et al., 2018, Hanser and Khoury, 2016, Hosseini et al., 2020, Huber et al., 2018, Hutton et al., 2018, Papi et al., 2020, Thoma et al., 2020b, Zafiropoulos et al., 2016).

General characteristics of studies assessing peri-implant mucosal changes using calipers

One study evaluated buccal MT changes utilizing a modified caliper (Wax caliper) approximately 2 mm apical to the free gingival margin (Rungcharassaeng et al., 2012) (Supplementary Table 5).

General characteristics of studies assessing peri-implant mucosal changes using cone-beam computed tomography (CBCT)

Among the included articles, two randomized controlled trials (De Bruyckere et al., 2018, Frizzera et al., 2019), two non-randomized comparative studies (Kato et al., 2018, Ko et al., 2020) and two case series (Chappuis et al., 2018, Kaminaka et al., 2015) utilized CBCT for assessing peri-implant mucosa alterations. The investigated intervention included implant placement alone, with hard or soft tissue augmentation (Supplementary Table 6). The software used for analyzing the CBCT data were the ones provided by the same company producing the CBCT device. Three studies reported that a dry cotton roll was placed in the vestibule, aiming at creating a gap between the lip and the alveolar process for a proper visualization of the hard and soft tissues on every slide (De Bruyckere et al., 2018, Kaminaka et al., 2015, Kato et al., 2018). The outcomes of interested included MT in all the six studies, with two of them investigating also STH (Kaminaka et al., 2015, Kato et al., 2018). The calibration of the examiners of the CBCT scans was report in five studies (Chappuis et al., 2018, De Bruyckere et al., 2018, Frizzera et al., 2019, Kaminaka et al., 2015, Kato et al., 2018) (Supplementary Table 6). Several reference points have been used for evaluating MT with CBCT (Supplementary Table 8), with thee studies out of six using the level of the implant shoulder as a landmark (Chappuis et al., 2018, Kaminaka et al., 2015, Kato et al., 2018).

General characteristics of studies assessing peri-implant mucosal changes using ultrasonography

Two randomized clinical trials (evaluating the same cohort of patients) utilized ultrasonography for assessing mucosal thickness variation (Puzio et al., 2018, Puzio et al., 2020). The other four studies were case series (Cardaropoli et al., 2006, De Bruyckere et al., 2015, Eghbali et al., 2016, Eghbali et al., 2018). Buccal MT change was assessed in all the six studies utilizing ultrasonography (Cardaropoli et al., 2006, De Bruyckere et al., 2015, Eghbali et al., 2016, Eghbali et al., 2018, Puzio et al., 2018, Puzio et al., 2020), with the article of Cardaropoli et al. that evaluated also the variation in the STH component (Cardaropoli et al., 2006). One study investigated peri-implant mucosa changes from the time of implant placement to 1-year post-loading (Cardaropoli et al., 2006), while the other studies aimed at assessing the MT gain following peri-implant soft tissue augmentation, either with connective tissue graft or xenogeneic collagen matrix (De Bruyckere et al., 2015, Eghbali et al., 2016, Eghbali et al., 2018, Puzio et al., 2018, Puzio et al., 2020). The frequency of the ultrasound device ranged from 5 to 20 MHz. A specific

calibration session or training for the examiners using ultrasonography was not described (Supplementary Table 7). A large heterogeneity was observed among the articles using ultrasonography in terms of reference points for measuring MT (Supplementary Table 8).

Supplementary table 2. Intervention, definition of the region of interest and volumetric outcomes of the included studies assessing volumetric changes with optical scanning-based digital technologies

Publication	Intervention	Region of interest (ROI) for calculating volumetric dimensional changes	Volumetric (Vol) changes from BL (mean ± SD) (mm^3)	Defect area (mean ± SD) (mm^2)	Mean distance between the two surfaces (ΔD) from BL (mean ± SD) (mm)	Linear dimensional (LD) changes from BL (mean ± SD) (mm)	Study conclusions
(Basler et al., 2018)	Implant placement and simultaneous GBR (resorbable membrane)	1 mm apical to the mucosal margin (coronal border of the ROI), extended 4-5 mm apically (remaining within the keratinized tissue). Mesio-distally, the ROI corresponded to the width of the single-tooth reconstruction	NR	NR	-0.22 ± 0.21 (at 1 year) * -0.3 ± 0.25 (at 3 years) *	-0.28 ± 0.29 (at 1mm at 1 year) * -0.41 ± 0.38 (at 3 mm at 1 year) * -0.37 ± 0.42 (at 1 mm at 3 years) * -0.56 ± 0.33 (at 3 mm at 3 years) *	A minor but ongoing loss of buccal contour was noticed without significant differences in the two groups
	Implant placement and simultaneous GBR (non-resorbable membrane)		NR	NR	-0.14 ± 0.3 (at 1 year) * -0.32 ± 0.22 (at 3 years) *	-0.28 ± 0.23 (at 1mm at 1 year) * -0.37 ± 0.14 (at 3 mm at 1 year) * -0.37 ± 0.29 (at 1mm at 3 years) * -0.59 ± 0.3 (at 3 mm at 3 years) *	
(Benic et al., 2017)	GBR	For the horizontal contour change the distance between the mucosal contours at the level 1 and 2 mm apical to the crown-mucosa margin	NR	NR	NR	1.77 ± 1.01 (1 mm, 3years), 1.23 ± 0.87 (2 mm, 3years)	Implant placement with simultaneous GBR resulted in a higher buccal soft tissue contour compared with implant placed without GBR. Abutment connection procedure increased the buccal contour of the marginal mucosa in both groups. However, GBR contributed more to the contour gain than did the abutment connection procedure.
	No augmentation		NR	NR	NR	0.63 ± 0.91 (1 mm, 3years) 0.54 ± 0.79 (2 mm, 3years)	

(Bertl et al., 2017)	Papilla augmentation with HY injection Papilla augmentation with saline solution (control group)	Delineated by a line connecting the gingival and mucosal margin of the adjacent tooth and implant-supported crown, respectively, and another line parallel to it located 3 mm more apically	NR NR	Volume change reported as an area 0.1 ± 0.23 Volume change reported as an area -0.02 ± 0.23	NR NR	NR NR	Injection of HY adjacent to maxillary anterior implant-supported crown did not show volume gain of deficient papillae
(Bittner et al., 2020)	IIP + IP with conventional titanium implant IIP + IP with a pink-neck implant	LD measured at 1, 2, 3, 4, 5 mm	NR	NR	NR	-0.68 ± 0.62 (thick biotype at 3mm) -0.97 ± 1.08 (thin biotype at 3mm) -0.53 ± 0.37 (thick biotype at 3mm) -0.56 ± 1.07 (thin biotype at 3mm)	In patients with thin biotype, using pink-neck implants can reduce the different in color between the peri-implant mucosa and adjacent gingiva
(Borges et al., 2020)	IIP	From the most apical point of the gingival margin of the adjacent teeth and ending 5 mm above it. Mesially and distally, a line passing thorough the interproximal area	-29.06 ± 21.25 at 12 months (for buccal plate thickness ≤ 1 mm) -11.89 ± 10.86 at 12 months (for buccal plate thickness > 1 mm)	NR	-0.59 ± 0.4 at 12 months (for buccal plate thickness ≤ 1 mm) -0.31 ± 0.22 at 12 months (for buccal plate thickness > 1 mm)	NR	Sites with thin buccal bone plates exhibited higher volume loss than sites with thicker buccal plate following IIP
(Cabanes-Gumbau et al., 2019)	Implant placement and soft tissue conditioning with the abutment and the provisional crown	Between the closest cuspids of the adjacent teeth (or 5 mm distal to the end of the crown if there was no distal tooth) and 4 mm apical to	38.6 ± 47.3 (Median volume increases of 5.2 and 58.2 for thin and thick	NR	0.56 ± 0.46	NR	Peri-implant soft tissue conditioning can promote a significant increase in soft tissue volume both at the level

		the soft tissue margin	biotypes, respectively)				
(Canullo et al., 2018)	Peri-implant soft tissue conditioning with abutments and crowns	Long axis of the restored implant and 2 mm mesially and distally	NR	NR	0.97 ± 0.19	NR	The use of a conical abutment together with the one-abutment one-time approach allowed longitudinal stable soft tissue dimensions
(Clementini et al., 2020)	IIP with XCM	Delimited by the gingival margin and the mucogingival line, and mesio-distally by the middle of interdental papillae	-32.50 ± 11.69	NR	-0.84 ± 0.30	-0.72 ± 0.23 (at 1 mm), -0.75 ± 0.26 (at 3 mm), -0.85 ± 0.27 (at 5 mm)	No differences in terms of linear and volumetric changes were observed between IIP with XCM, ARP or spontaneous healing
(De Bruyckere et al., 2020)	Implant placement with GBR	Coronal border 0.5 mm below the mucosal margin, apical border 4 mm higher up, mesial and distal line angle of the implant crown as mesial and distal borders	20.74 ± 9.22	16.65 ± 7.15	1.87 ± 0.82	NR	Similar effects of GBR and CTG in reestablishing buccal convexity
	Implant placement with CTG		15.86 ± 8.08	15.09 ± 3.75	1.73 ± 0.71	NR	
(Eeckhout et al., 2020)	Implant placement with PADM	0.5 mm below the soft tissue margin to 4 mm apical, with the mesial and distal line angle of the implant crown as mesial and distal borders	NR	NR	0.89 ± 0.45 (at 1 year) 1.17 ± 0.52 (at 3 years)	NR	Augmentation with PADM showed significant volume gain, however with marked resorption during the early stages of healing
(Fischer et al., 2019)	Peri-implant soft tissue augmentation with PADM	Delimited by the mesial and distal papillary midline, the mucogingival line and the crown margin	NR	NR	0.78	NR	PADM may provide consistent soft tissue augmentation that is maintained up to 24-month follow-up, although graft

							shrinkage may occur in the first 6 months
(Friberg and Jemt, 2012)	Peri-implant soft tissue augmentation with a synthetic scaffold	Line angles adjacent teeth, 8mm in apico-coronal direction	42.7 ± 21.1	NR	1.5 ± 0.66	NR	Soft tissue augmentation with a synthetic scaffold material resulted in an increased peri-implant soft tissue volume
(Galarraga-Vinueza et al., 2020)	Peri-implantitis treatment with implantoplasty (supracrestally) and GBR (intrabony component)	A standardized ROI (per case) was delimited with a digital pen. Mesial and distal papillae as horizontal limits, crown/abutment marginal contour coronally and using implant length as apical limit (per case)	NR	189.2 (baseline), 175 (1 month) and 158.9 (6 months)	-0.11 (1 month) -0.28 (6 months)	-0.61 (marginal region at 6 months), -0.25 (medial region at 6 months), -0.09 (apical region at 6 months)	Peri-implant mucosa showed considerable volumetric changes after combined surgical therapy
(Hinze et al., 2018)	IIP + IP with socket shield technique	Borders defined by a line parallel to the tooth axis in the middle of the mesial and distal papilla, the mucogingival line and the most coronal contour line of the alveolar ridge	NR	NR	-0.07 ± 0.16	NR	Soft tissue volume change (in terms of mean distance change) following IIP + IP with socket shield technique was < 0.5 mm in all cases
(Hosseini et al., 2020)	Implant placement with CTG at second stage	Three sagittal cross sections at the implant sites: one at the middle of the implant region and two others 2 mm mesially and 2 mm distally from the middle cross section	NR	NR	NR	1.02 ± 0.65 (at 1 mm), 1.51 ± 0.86 (at 3 mm), 1.63 ± 0.9 (at 5 mm)	Soft tissue augmentation with a CTG may result in better color match and more facial dimensional gain compared to implant sites without soft tissue grafting
	Implant placement without soft tissue augmentation		NR	NR	NR	0.53 ± 0.54 (at 1 mm), 0.59 ± 0.99 (at 3 mm), 0.62 ± 0.26 (at 5 mm)	

(Huber et al., 2018)	Peri-implant soft tissue augmentation with CTG	Trapezoid shape that the following borders: 1 mm apical of the mucosal mucosae (coronal), the mucogingival junction (apical) and 1 mm distance from the neighboring tooth (mesial, distal)	NR	NR	-0.2 ± 0.2	NR	Between crown insertion and 1 year, the buccal peri-implant soft tissue dimensions remained stable without relevant differences among the two groups
	Peri-implant soft tissue augmentation with XCM		NR	NR	-0.2 ± 0.5	NR	
(Jiang et al., 2020)	IIP + IP with CTG	Five horizontal lines drawn at the midfacial aspect, 1-5 mm apical to the bucco-coronal point of the buccal plate	NR	NR	NR	-0.89 ± 0.48 (at 1 mm), -0.54 ± 0.59 (at 3 mm), -0.18 ± 0.74 (at 5 mm)	The use of CTG showed significantly less buccal tissue collapse compared to the control group
	IIP + IP without soft tissue augmentation					-1.07 ± 0.45 (at 1 mm), -1.07 ± 0.62 (at 3 mm), -0.99 ± 0.82 (at 5 mm)	
(Papi et al., 2020)	Peri-implant soft tissue augmentation with PADM	Trapezoid shape, delimited coronally 1 mm apical to the soft tissue margin, apically by the mucogingival junction, with the mesial and distal borders 1 mm distant from the adjacent teeth	153.86	NR	NR	2.27 ± 0.08 (at 1 mm), 2.08 ± 0.04 (at 3 mm), 1.41 ± 0.13 (at 3 mm), 0.73 ± 0.06 (at 4 mm)	The use of PADM was effective in peri-implant soft tissue augmentation
(Parvini et al., 2020)	Peri-implant soft tissue augmentation with FGG	Based on the FGG perimeter (delineated with a digital pen)	NR	91 ± 50 (immediate post-op), 76.2 ± 48.2 (at 1 month), 61.3 ± 31 (at 3 months)	1.31 ± 0.2 (immediate post-op), 0.82 ± 0.47 (at 1 month), 0.37 ± 0.27 (at 3 months)	NR	FGG undergoes significant dimensional changes over a 3-month healing period

(Rojo et al., 2018)	Peri-implant soft tissue augmentation with CTG	Vestibular area, 2 mm to the mesial and distal angle, from 1 to 7 mm in an apical direction	NR	NR	NR	0.58 ± 0.32 (at 1 mm) 0.76 ± 0.42 (at 3mm) 0.54 ± 0.52 (at 5mm)	Both procedures were effective in increasing soft tissue volume with no statistically significant differences at 3 months
	Peri-implant soft tissue augmentation with tCTG		NR	NR	NR	0.68 ± 0.4 (at 1 mm) 0.81 ± 0.4 (at 3mm) 0.8 ± 0.44 (at 5mm)	
(Rojo et al., 2020)	Peri-implant soft tissue augmentation with CTG	Vestibular area, 2 mm to the mesial and distal angle, from 1 to 7 mm in an apical direction	NR	NR	NR	0.09 ± 0.1 (at 1 mm) 0.09 ± 0.23 (at 3mm) 0.03 ± 0.26 (at 5mm) (from 4 to 12 months after augmentation)	Both groups showed similar soft tissue stability between crown placement and 12 months
	Peri-implant soft tissue augmentation with tCTG		NR	NR	NR	0.17 ± 0.16 (at 1 mm) -0.01 ± 0.21 (at 3mm) 0 ± 0.19 (at 5mm) (from 4 to 12 months after augmentation)	
(Sanz Martin et al., 2016)	One-piece dental implants	Bordered by the mucosal margin at the implant restoration, by the mesial and distal line angles and extended 5-6 mm apically	NR	NR	-0.03 ± 0.29	-0.03 ± 0.35 (at 1 mm) 0.01 ± 0.28 (at 3 mm) -0.01 ± 0.51 (at 5 mm)	Within the first year of loading, minimal changes occur with regard to tissue thickness, crown height, and facial volume for both implant types
	Two-piece implants		NR	NR	-0.12 ± 0.27	-0.15 ± 0.2 (at 1 mm) -0.06 ± 0.2 (at 3 mm) -0.2 ± 0.51 (at 5 mm)	
(Sanz-Martin et al., 2019)	IIP + XCM + IP	Bordered by the mucosal margin at the implant restoration, by the mesial and distal line angles and extended 5-6 mm apically	-20.43 ± 11.70	NR	-0.82 ± 0.64 mm	-1.01 ± 0.67 (at 1 mm) -0.96 ± 0.69 (at 3 mm) -1.01 ± 0.93 (at 5 mm)	The tested protocol resulted in a significant reduction of the tissue contours and osseous ridge dimensions that was partially compensated by a non-significant increase in soft tissue thickness

(Sapata et al., 2018)	One-piece dental implants	Bordered by the mucosal margin, mesial and distal line angles and extending 3-6 mm apically	NR	NR	-0.48 ± 0.33	-0.63 ± 0.46 (at 1 mm) -0.56 ± 0.43 (at 3 mm) -0.53 ± 0.64 (at 5 mm)	Minimal profilometric and linear changes occurred at implant sites between baseline and 5 years
	Two-piece implants		NR	NR	-0.45 ± 0.47	-0.72 ± 0.51 (at 1 mm) -0.53 ± 0.37 (at 3 mm) -0.6 ± 0.52 (at 5 mm)	
(Schneider et al., 2011)	GBR at the time of implant placement	NR	NR	18.97 ± 6.59	0.72 ± 0.47	NR	The clinical protocol was effective in augmenting peri-implant tissue that remained stable to a high degree within 1 year after crown insertion
	CTG (6 months after implant and GBR)		NR	18.97 ± 6.59	0.55 ± 0.53	NR	
	Overall augmentation (GBR + CTG)		NR	NR	1.27 ± 0.67	NR	
(Thoma et al., 2020b)	Peri-implant soft tissue augmentation with CTG	Trapezoid shape that the following borders: 1 mm apical of the mucosal mucosae (coronal), the mucogingival junction (apical) and 1 mm distance from the neighboring tooth (mesial, distal).	NR	NR	-0.2 ± 0.3	NR	Minimal changes of the peri-implant tissue contour as well as of the soft tissue thickness were observed at implant sites previously grafted with CTG or XCM
	Peri-implant soft tissue augmentation with XCM		NR	NR	-0.3 ± 0.4	NR	
(Tian et al., 2019)	IIP + IP	NR	NR	NR	-0.62 ± 0.22	NR	The labial soft tissue contour showed a continuous alteration resulting in a mean change in thickness of 0.62 mm that occurred

							mainly in the first 3 months and then it tended to be relatively stable after 6 months.
(van Nimwegen et al., 2018)	IIP + IP + CTG	1-2 mm apically to the gingival margin, border of the mesial and distal papilla adjacent to the implant crown and the mucogingival line (apically)	-9.32 ± 7.19	11.97 ± 4.43	-0.68 ± 0.59	NR	The use of CTG during IIP + IP did not result in less mucosal volume after 1 year, leading to the assumption that a CTG cannot fully compensate for the facial bone loss, although a significant more coronally located mid-facial mucosal level was found when a CTG was performed
	IIP + IP without CTG		-7.77 ± 7.26	13.45 ± 3.56	-0.49 ± 0.54	NR	
(Wang et al., 2019)	IIP + IP	Lower and upper boundaries at 2 and 6 mm above the mid-facial margin and enclosed by two bucco-lingual cross-sectional planes crossing the mesial and distal papilla	-0.11 ± 0.07 (Volume loss 11.9%)	NR	NR	-0.5 ± 0.5 (at 2 mm), -0.5 ± 0.4 (at 4 mm)	Linear changes of facial soft-tissue resorption at immediately placed implants were independent of immediate provisionalization. However, the test group (immediate provisionalization) preserved higher tissue volume at 1 year compared to control group (healing abutment)
	IIP without IP		-0.17 ± 0.08 (Volume loss 17.4%)	NR	NR	-0.5 ± 0.4 (at 2 mm), -0.7 ± 0.5 (at 4 mm)	
(Wei et al., 2019)	IIP + IP	NR	NR	NR	-0.62 ± 0.22	-0.54 ± 0.48 (at 1 mm), -0.96 ± 0.52 (at 3 mm), -0.89 ± 0.57 (at 5 mm)	After 1 year the free gingival margin is stable with only mild recession, with a mean facial soft tissue contour collapse of 0.62 mm

(Wittnebe n et al., 2016)	Peri-implant soft tissue conditioning with provisional restorations	Individually shaped mucosal margin, including the inner soft tissue contour and the outline of the standardized circular healing abutment	41.9 ± 20.3 (for maxillary central incisors) and 25.8 ± 10.4 (for maxillary lateral incisors). On average 33.9 ± 17	NR	NR	NR	The peri-implant soft tissue volume increased more than twofold after conditioning with prefabricated healing abutment
(Zeltner et al., 2017)	Peri-implant soft tissue augmentation with CTG	Crestal ROI: trapezoid shape located at the crestal aspect of the grafted area determined by the midcrestal line and the gingival margins of the adjacent teeth.	NR	NR	0.79 ± 0.45 (buccal) 0.42 ± 0.74 (crestal)	NR	XCM and CTG resulted in similar peri-implant volume gain in the short-term
	Peri-implant soft tissue augmentation with XCM	Buccal ROI: trapezoid shape and defined as the area between the margins of the adjacent teeth, the mucogingival junction as apical and the interproximal areas as lateral borders	NR	NR	0.77 ± 0.74 (buccal) 0.27 ± 0.26 (crestal)	NR	

Legend. ARP: alveolar ridge preservation. BL: baseline. CTG: connective tissue graft. FGG: free gingival graft. GBR: guided bone regeneration. HY: hyaluronan. IIP: immediate implant placement. IP: immediate provisionalization. LD: linear dimensional change. NR: not reported. PADM: porcine dermal matrix. RCT: randomized clinical trial. tCTG: connective tissue graft from the maxillary tuberosity. Vol: volumetric change in mm^3. XCM: xenogeneic collagen matrix. ΔD: mean distance between the surfaces/mean thickness of the reconstructed volume. * changes from prosthetic delivery (when implant placement and bone augmentation had been already performed) to the follow-up.

Supplementary table 3. Summary of the interventions in which optical scanning-based digital technologies were utilized

Clinical scenario	Intervention	References
Immediate implant placement	With immediate provisionalization	(Bittner et al., 2020, Jiang et al., 2020, Tian et al., 2019, van Nimwegen et al., 2018, Wang et al., 2019, Wei et al., 2019)
	Without immediate provisionalization	(Borges et al., 2020, Clementini et al., 2020, Wang et al., 2019)
Implant placement	With CTG	(Jiang et al., 2020, Sanz-Martin et al., 2019, van Nimwegen et al., 2018)
	Socket shield	(Hinze et al., 2018)
	With simultaneous GBR	(Basler et al., 2018, Benic et al., 2017, De Bruyckere et al., 2020, Schneider et al., 2011)
	No grafts, abutment connection procedure only	(Benic et al., 2017, Hosseini et al., 2020, Sanz Martin et al., 2016, Sapata et al., 2018)
	Soft tissue conditioning with abutments and provisional crowns	(Cabanes-Gumbau et al., 2019, Canullo et al., 2018, Wittneben et al., 2016)
Surgical treatment of peri-implantitis	Implantoplasty (supracrestally) and GBR (intrabony component)	(Galarraga-Vinueza et al., 2020)
Soft tissue augmentation at implant sites	With CTG	(De Bruyckere et al., 2020, Huber et al., 2018, Rojo et al., 2018, Rojo et al., 2020, Thoma et al., 2020b, Zeltner et al., 2017, Hosseini et al., 2020, Schneider et al., 2011)
	With FGG	(Parvini et al., 2020)
	With XCM	(Huber et al., 2018, Thoma et al., 2020b, Zeltner et al., 2017)
	With PADM	(Eeckhout et al., 2020, Fischer et al., 2019, Papi et al., 2020)
	With a synthetic scaffold	(Friberg and Jemt, 2012)

Legend. BL: baseline. CTG: connective tissue graft. FGG: free gingival graft. GBR: guided bone regeneration. PADM: porcine dermal matrix. XCM: xenogeneic collagen matrix.

Supplementary table 4. Characteristics of the included studies assessing peri-implant mucosa alterations using transgingival piercing (TP) methods.

Publication	Study design	Country, Setting, Funding	Treatment	Follow-up time	Participant (n), age (years), sites (n)	Mucosa alteration outcomes	Instruments used for TP	Measure Stop	Instruments for thickness assessment	Calibration and blinding of the examiner(s)
(Anderson et al., 2014)	RCT	USA, University, sponsored	PSTD treatment with ADM or CTG	3 and 6 months	13, NR, 13	MT	Endodontic files	Stoppers	NR	NR
(Andreasi Bassi et al., 2016)	Prospective case series	Italy, Private practice, Self-supported	Peri-implant soft tissue augmentation with connective punch	3-4 months and 1 year	14, 48.07, 17	MT	#15 k-file	Silicon disk stop	NR	NR
(Bashutski et al., 2013)	RCT	USA, University, materials donated	Flapless vs traditional implant placement	3, 6, 9 and 15 months	24, 52.8, 24	MT	Endodontic files	Silicon disk stop	NR	Calibrated and blinded
(Cairo et al., 2017)	RCT	Italy, University, sponsored	Peri-implant soft tissue augmentation with CTG or XCM	3 and 6 months	30, 49.3, 30	MT	Injection needle for anesthesia	Silicon disk stop fixed with cyanoacrylate	Digital caliper (0.01 mm accuracy)	Calibrated and blinded
(Clementini et al., 2019)	RCT	Italy, University, sponsored	Immediate implant placement with XCM vs ARP or spontaneous healing (with delayed implant placement)	4 months	10, 52.5, 10 (in the immediate implant placement with XCM group)	MT	Injection needle for anesthesia	Silicon disk stop	Digital caliper (0.1 mm accuracy)	Calibrated and blinded
(D'Elia et al., 2017)	RCT	Italy, University, sponsored	Peri-implant augmentation with CTG or GBR	6 months and 1 year	16, 47.6, 16	MT	#15 endodontic instrument	Silicon disk stop	Periodontal probe	Calibrated and blinded
(Eisner et al., 2018)	RCT	Switzerland, University,	Implant restored with or without abutment	BL, 1 year and 3 years	18, 50, 18	MT	Endodontic file	Rubber stop	NR	NR

		self-supported	modification (pink veneering ceramic)							
(Farina and Zaffe, 2015)	RCT	Italy, University, self-supported	Peri-implant soft tissue augmentation with ADM	4 months	27, 60.3, 47	STH	Periodontal probe (Cp15, Hu-Friedy, Chicago, USA) and #40 Hedstrom file	Periodontal probe	Periodontal probe	NR
(Froum et al., 2015)	RCT	USA, University, sponsored	Peri-implant soft tissue augmentation with XCM vs non-augmented sites	3 months	31, NR, 31	MT	Silver point	NR	Boley gauge	Calibrated and blinded
(Fu et al., 2014)	RCT	USA, University, sponsored	Hard tissue augmentation at implant placement (with or without membrane)	6 months	26, 48.6, 26	MT	K-flex file s#30	Rubber stop	Endodontic finger ruler	Calibrated and blinded
(Guarnieri et al., 2019b)	Prospective case series	Italy, University, self-supported	Implant placement	3 years	30, 48.9, 30	MT	K-file #30	NR	NR	Calibrated
(Hanser and Khoury, 2016)	Case series	Germany, Private practice, self-supported	Implant placement with CTG	1 year and 5 years	46, 37.8, 52	MT	Periodontal probe (NR)	Acrylic stent and probe	NR	NR
(Hosseini et al., 2020)*	Prospective non-randomized comparative study	Denmark, University, self-supported	Implant placement with or without CTG at second stage	1, 3 and 5 years	19, 22, 33	MT	Endodontic file (Hedestrom #20)	Silicon disk stop	Digital caliper (0.1 mm accuracy)	NR
(Huber et al., 2018)*	RCT	Switzerland, University, sponsored	Peri-implant soft tissue augmentation with CTG or XCM	1 year	20, 43.3, 20	MT	K-file 31/15	Silicon disk stop	NR	Calibrated and blinded
(Hutton et al., 2018)	RCT	USA, University, sponsored	Implant placement with soft tissue augmentation with ADM or CTG	4 months	10, 55.5, 10	MT	Periodontal probe (UNC, Hu-Friedy, Chicago, USA) and endodontic spreader	Silicon disk stop	NR	Calibrated and blinded

(Linkevicius et al., 2015a)	Prospective non-randomized comparative study	Lithuania, NR, self-supported	Implant placement with or without ADM	1 year	103, 45.3, 103	STH	Periodontal probe (UNC, Hu-Friedy, Chicago, USA)	Periodontal probe	Periodontal probe	NR
(Migliorati et al., 2015)	RCT	Italy, University, NR	Immediate implant placement with or without CTG	1 year and 2 years		MT	Endodontic reamer	Rubber stop	Caliper	Blinded
(Papapetros et al., 2019)	RCT	Greece, University, self-supported	Implant placement with or without CTG	3/4 months	46, 48.5, 46	MT, STH	Periodontal probe (XP-23/QW, Hu-Friedy, Chicago, USA)	Silicon disk stop	Digital caliper	Calibrated
(Papi et al., 2019)	Prospective case series	Italy, University, self-supported	Implant placement with PADM	1 year	10, 56.9, 10	MT	Endodontic file	Rubber stop	Digital caliper (0.01 mm accuracy)	NR
(Papi et al., 2020)*	Prospective case series	Italy, University, materials donated	Peri-implant soft tissue augmentation with PADM	1 year	12, 51.6, 12	MT	Endodontic file	Silicon disk stop fixed with cyanoacrylate	Digital caliper (0.1 mm accuracy)	Calibrated
(Poli et al., 2019)	RCT	Italy, University, self-supported	Peri-implant soft tissue augmentation with CTG at the time of implant placement or at second stage	3, 6, 9 and 1 year	14, 49.4, 14	MT	Endodontic K-file	Silicon disk stop	Digital caliper	Calibrated and blinded
(Puisys et al., 2015)	Prospective case series	Lithuania, NR, NR	Implant placement with ADM	3 months	40, 42.5, 40	STH	Periodontal probe (UNC, Hu-Friedy, Chicago, USA)	Periodontal probe	Periodontal probe	NR
(Schallhorn et al., 2015)	Prospective case series	USA, University, sponsored	Peri-implant soft tissue augmentation with XCM	6 months	30, NR, 35	MT	Flex files	Silicon disk stop	NR	No
(Stefanini et al., 2016)	Prospective case series	Italy, University, self-supported	Implant placement with CTG	1 and 3 years	20, NR, 20	MT	Injection needle for anesthesia	Silicon disk stop	Digital caliper (0.1 mm accuracy)	NR

(Stefanini et al., 2020)	Prospective case series	Italy, University, sponsored	PSTD treatment with PADM	1 year	10, 48.1, 10	MT	Injection needle for anesthesia	Silicon disk stop fixed with cyanoacrylate	Digital caliper (0.1 mm accuracy)	NR
(Thoma et al., 2016)	RCT	Switzerland, University, sponsored	Peri-implant soft tissue augmentation with CTG or XCM	3 months	20, 43.3, 20	MT and STH	K-file 31/15	Silicon disk stop	NR	Calibrated and blinded
(Thoma et al., 2020b)*	RCT	Switzerland, University, sponsored	Peri-implant soft tissue augmentation with CTG or XCM	36 months	17, NR, 17	MT	K-file 31/15	Silicon disk stop	NR	Blinded
(Torkzaban et al., 2015)	Prospective non-randomized comparative study	Iran, University, self-supported	Submerge vs non submerged implant placement	3, 6 and 12 months	48, 41.4, 48	MT	Endodontic file #20	Rubber stop	Digital caliper	Calibrated and blinded
(Ustaoğlu et al., 2020)	RCT	Turkey, University, NR	Implant placement with CTG or t-PRF	3 months	30, 30	MT and STH	Endodontic spreader	Rubber stop	Digital caliper	Calibrated and blinded
(Verardi et al., 2019)	Prospective non-randomized comparative study	USA and Italy, University and private practice, self-supported	Implant placement with PADM or GBR	6 months	47, 58.3, 47	STH	Periodontal probe (UNC, Hu-Friedy, Chicago, USA)	Periodontal probe	Periodontal probe	NR
(Wiesner et al., 2010)	RCT	Austria, Private practice, NA	Implant placement with or without CTG	1 year	20, 39, 20	MT	Endodontic micro-opener	Silicon disk stop	Endodontic longimetre	Blinded
(Zafiropoulos et al., 2016)	RCT	Italy, University, materials donated	Implant placement with or without PADM	6 months	27, 46.1, 27	MT	#15 endodontic reamer	Silicon disk stop fixed with cyanoacrylate	Gauge	Blinded

(Zucchelli et al., 2013)	Prospective case series	Italy, University, self-supported	PSTD treatment with CTG	1 year	20, NR, 20	MT	Injection needle for anesthesia	Silicon disk stop fixed with cyanoacrylate	Digital caliper (0.1 mm accuracy)	NR
(Zucchelli et al., 2018)	Prospective case series	Italy, University, self-supported	PSTD treatment with CTG	1 and 5 years	19, NR, 19	MT	Injection needle for anesthesia	Silicon disk stop fixed with cyanoacrylate	Digital caliper (0.1 mm accuracy)	NR

Legend. ADM: acellular dermal matrix. ARP: alveolar ridge preservation. CTG: connective tissue graft. GBR: guided bone regeneration. MT: mucosal thickness (on the facial aspect of the implant). NR: not reported. PADM: porcine-derived acellular dermal matrix. PSTD: peri-implant soft tissue dehiscence. RCT: Randomized clinical trial. STH: supracrestal tissue height (on the occlusal/crestal aspect of the implant). t-PRF: titanium-prepared platelet-rich fibrin. XCM: xenogeneic collagen matrix. * studies also analyzing volumetric changes with optical scanning-based technologies.

Supplementary table 5. Characteristics of the included studies assessing peri-implant mucosa variation using calipers

Publication	Study design	Country, Setting, Funding	Treatment	Follow-up time (months)	Participant (n), age (years), sites (n)	Mucosa alteration outcomes	Type of caliper	Reference points	Calibration and blinding of the examiner(s)
(Rungcharassaeng et al., 2012)	Prospective non-randomized comparative study	USA, University, NR	Immediate implant placement with or without CTG	Prosthesis delivery (8.6 months on average)	24, 45.4, 24	MT	Modified caliper (Wax Caliper)	Approximately 2 mm apical to the free gingival margin	NR

Legend. CTG: connective tissue graft. MT: mucosal thickness (on the facial aspect of the implant). NR: not reported.

Supplementary table 6. Characteristics of the included studies assessing peri-implant mucosa variation using cone beam computed tomography

Publication	Study design	Country, Setting, Funding	Treatment	Follow-up time (months)	Participant (n), age (years), sites (n)	Type of CBCT	Software used for analyzing the CBCT imaging	Peri-implant mucosa alterations outcomes	Other approaches for measuring mucosa alterations outcomes	Calibration and blinding of the examiner(s) of CBCT scans
(Chappuis et al., 2018)	Prospective case series	Switzerland, University, sponsored	Implant placement and simultaneous GBR	6 and 10 years	20, 53, 20	3D Accuitomo 170 (Morita, Kyoto, Japan)	i-Dixel (Morita, Kyoto, Japan)	MT	No	Calibrated
(De Bruyckere et al., 2018)	RCT	Belgium, University, materials donated	Implant placement and simultaneous CTG or GBR	2 weeks and 1 year	42, 51, 42	PaX-i3d Green (Vatech, Gyeonggi-do, South Korea)	Ez3D-Plus (Vatech, Gyeonggi-do, South Korea)	MT	No	Calibrated and blinded
(Frizzera et al., 2019)	RCT	Brazil, University, materials donated	Immediate implant placement, either with CTG, XCM or without soft tissue grafts	6 months and 1 year	24, NR, 24	NR	NR	MT	No	Blinded
(Kaminaka et al., 2015)	Prospective case series	Japan, University, self-supported	Implant placement	1 year	32, 63, 34	(Asahi Roentgen, Japan)	Neo Premium software (Asahi Roentgen, Japan)	MT and STH	No	Calibrated
(Kato et al., 2018)	Prospective non-randomized comparative study	Japan, University, NR	Implant placement alone, with GBR and/or with CTG	1 year	34, 53.7, 34	NR	Neo Premium software (Asahi Roentgen, Japan)	MT and STH	No	Calibrated
(Ko et al., 2020)	Prospective non-	Korea, Universit	Implant placement	1 year	30, 56.9, 31	NR	NR	MT	No	NR

randomized comparative study	y, sponsored	with or without GBR. APF + XCM at second stage.

Legend. CTG: connective tissue graft. GBR: guided bone regeneration. MT: mucosal thickness (on the facial aspect of the implant). NR: not reported. RCT: Randomized clinical trial. STH: supracrestal tissue height (on the occlusal/crestal aspect of the implant). XCM: xenogeneic collagen matrix.

Supplementary table 7. Characteristics of the included studies assessing peri-implant mucosa variation using ultrasonography

Publication	Study design	Country, Setting, Funding	Treatment	Time points	Participant (n), age (years), sites (n)	Type of US device used	Ultrasound frequency (MHz)	Peri-implant mucosa alterations outcomes	Other approaches for measuring mucosa alterations outcomes	Calibration and blinding of the examiner(s) of US scans
(Cardaropoli et al., 2006)	Prospective case series	Sweden, University, NR	Implant placement	Abutment connection and 12 months	11, 26, 11	SDM (Krupp Corp., Essen, Germany)	NR	MT and STH	No	NR
(De Bruyckere et al., 2015)	Prospective case series	Belgium, University, sponsored	Peri-implant soft tissue augmentation with CTG	Immediate post-op, 2 weeks and 9 months	37, 38, 37	EPOCH (Olympus, Aartselaar, Belgium)	5	MT	No	No
(Eghbali et al., 2016)	Prospective case series	Belgium, University, sponsored	Peri-implant soft tissue augmentation with CTG	Immediate post-op, 3 and 9 months	10, 52, 10	EPOCH (Olympus, Aartselaar, Belgium)	5	MT	No	No
(Eghbali et al., 2018)	Prospective case series	Belgium, University, sponsored	Peri-implant soft tissue augmentation with CTG	Immediate post-op, 1 year and 5 years	32, 38, 32	EPOCH (Olympus, Aartselaar, Belgium)	5	MT	No	NR
(Puzio et al., 2018, Puzio et al., 2020)	RCT	Poland, University, sponsored	Implant placement with soft tissue augmentation (either with CTG or XCM)	3 months and 1 year	57, 41.7, 75	Pirop dental ultrasound device (Echoson Company, Poland)	20	MT	No	NR

Legend. BL: baseline. CTG: connective tissue graft. MHz: Megahertz. MT: mucosal thickness (on the facial aspect of the implant). NR: not reported. RCT: Randomized clinical trial. STH: supracrestal tissue height (on the occlusal/crestal aspect of the implant). US: Ultrasound. XCM: xenogeneic collagen matrix.

Supplementary table 8. Reference points used for measuring mucosal thickness variations

Method	Reference point(s)	Study
Transgingival piercing	1 mm and 3 mm apical to the soft tissue margin	(Anderson et al., 2014, Hosseini et al., 2020, Huber et al., 2018, Thoma et al., 2020b, Zafiropoulos et al., 2016)
	1 mm, 2 mm and 5 mm apical to the soft tissue margin	(Andreasi Bassi et al., 2016)
	1 mm, 3 mm and 5 mm apical to the soft tissue margin	(Hutton et al., 2018)
	3 mm apical to the soft tissue margin	(Clementini et al., 2019)
	2 mm apical to the bone crest	(D'Elia et al., 2017)
	2 mm and 4 mm apical to the bone crest	(Papapetros et al., 2019)
	1 mm apical to the soft tissue margin	(Eisner et al., 2018)
	1 mm apical to the sulcus	(Torkzaban et al., 2015)
	1.5 mm apical to the soft tissue margin	(Schallhorn et al., 2015, Stefanini et al., 2020)
	2 mm apical to the soft tissue margin	(Stefanini et al., 2016)
	2 mm and 5 mm apical to the soft tissue margin	(Hanser and Khoury, 2016)
	1 mm coronal to the mucogingival junction	(Cairo et al., 2017, Froum et al., 2015, Papi et al., 2019, Poli et al., 2019, Papi et al., 2020, Ustaoğlu et al., 2020)
	In the middle of apico-coronal width of the keratinized tissue	(Migliorati et al., 2015)
Caliper	2 mm apical to the free gingival margin	(Rungcharassaeng et al., 2012)
CBCT	At the level of the implant shoulder	(Kaminaka et al., 2015, Chappuis et al., 2018, Kato et al., 2018)
	1 mm coronal to the implant platform	(De Bruyckere et al., 2018)
	1, 3, 5 mm apical to the implant platform	(De Bruyckere et al., 2018)
	2 mm apical to the implant platform	(Kaminaka et al., 2015, Kato et al., 2018)
	2 mm below the soft tissue margin	(Frizzera et al., 2019)
Ultrasonography	On the line connecting the CEJ of adjacent teeth on the gingival margin	(Puzio et al., 2018, Puzio et al., 2020)
	At the level of the MGJ along the axis of the implant	(Puzio et al., 2018, Puzio et al., 2020)
	Lower border of the transducer at the level of the free mucosal margin	(De Bruyckere et al., 2015, Eghbali et al., 2016, Eghbali et al., 2018)

Legend. CBCT: cone beam computed tomography. CEJ: cemento-enamel junction. MGJ: mucogingival junction.

Risk of bias assessment

Forty-seven studies were considered to have a low risk of bias (Bashutski et al., 2013, Benic et al., 2017, Bertl et al., 2017, Borges et al., 2020, Cabanes-Gumbau et al., 2019, Cairo et al., 2017, Canullo et al., 2018, Cardaropoli et al., 2006, Chappuis et al., 2018, Clementini et al., 2019, Clementini et al., 2020, D'Elia et al., 2017, De Bruyckere et al., 2020, De Bruyckere et al., 2018, De Bruyckere et al., 2015, Eghbali et al., 2016, Eghbali et al., 2018, Froum et al., 2015, Fu et al., 2014, Galarraga-Vinueza et al., 2020, Hosseini et al., 2020, Hutton et al., 2018, Jiang et al., 2020, Kato et al., 2018, Ko et al., 2020, Migliorati et al., 2015, Papapetros et al., 2019, Rojo et al., 2018, Rojo et al., 2020, Rungcharassaeng et al., 2012, Sanz Martin et al., 2016, Sanz-Martin et al., 2019, Schneider et al., 2011, Stefanini et al., 2016, Stefanini et al., 2020, Thoma et al., 2020b, Thoma et al., 2016, Tian et al., 2019, Torkzaban et al., 2015, Verardi et al., 2019, Wang et al., 2019, Wei et al., 2019, Wiesner et al., 2010, Zafiropoulos et al., 2016, Zeltner et al., 2017, Zucchelli et al., 2018, Zucchelli et al., 2013), while twenty-four were judged to have a moderate risk of bias (Anderson et al., 2014, Andreasi Bassi et al., 2016, Basler et al., 2018, Eeckhout et al., 2020, Fischer et al., 2019, Friberg and Jemt, 2012, Frizzera et al., 2019, Guarnieri et al., 2019b, Hanser and Khoury, 2016, Hinze et al., 2018, Huber et al., 2018, Kaminaka et al., 2015, Linkevicius et al., 2015a, Papi et al., 2019, Papi et al., 2020, Parvini et al., 2020, Poli et al., 2019, Puisys et al., 2015, Puzio et al., 2018, Puzio et al., 2020, Sapata et al., 2018, Schallhorn et al., 2015, van Nimwegen et al., 2018, Wittneben et al., 2016) and the remaining four articles had a high risk of bias (Bittner et al., 2020, Eisner et al., 2018, Farina and Zaffe, 2015, Ustaoğlu et al., 2020).

Risk of bias assessment is explained in detailed in Supplementary tables 9-11.

Supplementary Table 9. Bias risk assessment for the included RCTs using The Cochrane Risk of Bias Tool for Randomized Controlled Trials.

Publication	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data addresses	Selective reporting	Other bias	Overall risk of bias
(Anderson et al., 2014)	low	low	low	low	low	low	unclear	moderate
(Bashutski et al., 2013)	low	low	low	low	low	low	low	low
(Basler et al., 2018)	low	low	low	unclear	low	low	low	moderate
(Bertl et al., 2017)	low	low	low	low	low	low	low	low
(Bittner et al., 2020)	low	low	unclear	unclear	low	low	low	high
(Cairo et al., 2017)	low	low	low	low	low	low	low	low
(Clementini et al., 2019)	low	low	low	low	low	low	low	low
(Clementini et al., 2020)	low	low	low	low	low	low	low	low
(D'Elia et al., 2017)	low	low	low	low	low	low	low	low
(De Bruyckere et al., 2018)	low	low	low	low	low	low	low	low
(De Bruyckere et al., 2020)	low	low	low	low	low	low	low	low
(Eisner et al., 2018)	low	low	unclear	unclear	low	low	low	high
(Farina and Zaffe, 2015)	low	low	unclear	unclear	low	low	low	high
(Frizzera et al., 2019)	unclear	low	low	low	low	low	low	moderate
(Froum et al., 2015)	low	low	low	low	low	low	low	low
(Fu et al., 2014)	low	low	low	low	low	low	low	low
(Huber et al., 2018)	low	low	low	unclear	low	low	low	moderate
(Hutton et al., 2018)	low	low	low	low	low	low	low	low

(Jiang et al., 2020)	low	low	low	low	low	low	low	low
(Migliorati et al., 2015)	low	low	low	low	low	low	low	low
(Papapetros et al., 2019)	low	low	low	low	low	low	low	low
(Poli et al., 2019)	low	low	low	unclear	low	low	low	moderate
(Puzio et al., 2018)	low	low	low	low	low	low	unclear	moderate
(Puzio et al., 2020)	low	low	low	low	low	low	unclear	moderate
(Rojo et al., 2018)	low	low	low	low	low	low	low	low
(Rojo et al., 2020)	low	low	low	low	low	low	low	low
(Sanz Martin et al., 2016)	low	low	low	low	low	low	low	low
(Sapata et al., 2018)	low	low	unclear	low	low	low	low	moderate
(Thoma et al., 2016)	low	low	low	low	low	low	low	low
(Thoma et al., 2020b)	low	low	low	low	low	low	low	low
(Ustaoğlu et al., 2020)	low	low	unclear	low	low	low	unclear	high
(van Nimwegen et al., 2018)	low	low	unclear	low	low	low	low	moderate
(Wang et al., 2019)	low	low	low	low	low	low	low	low
(Wiesner et al., 2010)	low	low	low	low	low	low	low	low
(Zafiropoulos et al., 2016)	low	low	low	low	low	low	low	low
(Zeltner et al., 2017)	low	low	low	low	low	low	low	low

Supplementary Table 10. Risk of bias assessment for non-randomized comparative studies of interventions according to the ROBINS-I tool

Publication	Bias due to confounding	Bias in selection of participants	Bias in classification of intervention	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall risk of bias
(Benic et al., 2017)	no	no	no	no	no	no	no	low
(Hosseini et al., 2020)	no	no	no	no	no	no	no	low
(Kato et al., 2018)	no	no	no	no	no	no	no	low
(Ko et al., 2020)	no	no	no	no	no	no	no	low
(Linkevicius et al., 2015a)	no	no	no	no	no	yes	no	moderate
(Rungcharassaeng et al., 2012)	no	no	no	no	no	no	no	low
(Torkzaban et al., 2015)	no	no	no	no	no	no	no	low
(Verardi et al., 2019)	no	no	no	no	no	no	no	low

Supplementary Table 11. Risk of bias assessment for case series according to The Joanna Briggs Institute Critical Appraisal tool

Publication	Were there clear criteria for inclusion?	Was the condition measured in a standard, reliable way for all participants?	Were valid methods used for identification of the condition for all participants?	Did the case series have consecutive inclusion of participants?	Did the case series have complete inclusion of participants?	Was there clear reporting of the demographics of the participants?	Was there clear reporting of clinical information of the participants?	Were the outcomes or follow-up results clearly reported?	Was there clear reporting of the presenting site (s)/clinic(s) demographic information	Was the statistical analysand appropriate?	Overall risk of bias
(Andreasi Bassi et al., 2016)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Borges et al., 2020)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Cabanes-Gumbau et al., 2019)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Canullo et al., 2018)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Cardaropoli et al., 2006)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Chappuis et al., 2018)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(De Bruyckere et al., 2015)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Eeckhout et al., 2020)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Eghbali et al., 2016)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Eghbali et al., 2018)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Fischer et al., 2019)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Friberg and Jemt, 2012)	no	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Galarraga-Vinueza et al., 2020)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Guarnieri et al., 2019b)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate

(Hanser and Khoury, 2016)	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	moderate
(Hinze et al., 2018)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Kaminaka et al., 2015)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Papi et al., 2019)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Papi et al., 2020)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Parvini et al., 2020)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Puisys et al., 2015)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Sanz-Martin et al., 2019)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Schallhorn et al., 2015)	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
Schneider et al., 2011)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Stefanini et al., 2016)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Stefanini et al., 2020)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Tian et al., 2019)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Wei et al., 2019)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Wittneben et al., 2016)	no	yes	yes	no	yes	yes	yes	yes	yes	yes	moderate
(Zucchelli et al., 2013)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low
(Zucchelli et al., 2018)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	low

Limitations of the present review

This review is not exempt of limitations. Twenty-four of the included studies were considered to have moderate risk of bias and four articles were classified as having high risk of bias. Therefore, readers should bear this in mind when interpreting our results.

The large heterogeneity between the different methods used for assessing volumetric changes at implant sites prevented performing quantitative comparisons. In addition, there was a large variability between and within the different techniques in terms of reference points at different apico-coronal planes utilized for assessing mucosal thickness and linear dimensional changes.

Several of the included studies using optical scanning-based technologies did not provide sufficient data on the key parameters associated with volume changes (volume changes in mm^3, the mean distance between the surfaces/mean thickness of the reconstructed volume [ΔD] and linear dimensional changes at different apico-coronal levels). In addition, only few articles provided volumetric data for certain treatment protocols (e.g. immediate implant placement with connective tissue graft) and therefore a meta-analysis was not performed. Nevertheless, it should be highlighted that the region of interest (ROI) highly affects the volume gain in mm^3 and therefore, the estimated Vol should be interpreted with caution. It would have been advantageous if more studies reported on how they calculate their ROI and if the examiner for the 3D data collection and analysis was blinded or calibrated. The lack of a standardized method for identifying ROIs makes quantitative comparisons between studies impossible. Therefore, we have recommended guidelines for defining ROIs.

Additionally, it has to be mentioned that the accuracy of STL files originating from indirect techniques may have been negatively affected by the extra steps required (compared to the direct technique), including distortion of the impression materials used, and protocol followed to produce the casts. This aspect seems to be particularly crucial given the fact that we are considering alterations within less than a millimeter. The ideal indirect technique should use a high-fidelity elastomeric impression material and follow strict protocols to provide an adequate cast for digitalization.

In addition, although the reliability and reproducibility of digital technologies have been previously demonstrated (Windisch et al., 2007, Lehmann et al., 2012, Igathinathane et al., 2010, Schneider et al., 2014) it would have been beneficial/interesting if some of the studies had compared changes in soft tissue thickness assessed via conventional transgingival probing relative to the volumetric outcomes obtained through digital analyses.

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