THE JOURNAL OF PROSTHETIC DENTISTRY

SYSTEMATIC REVIEW

Effectiveness of immediate implant placement into defective sockets in the esthetic zone: A systematic review and meta-analysis

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ABSTRACT

Statement of problem. A defective socket is common after tooth extraction in the esthetic zone, but whether an implant can be immediately placed in a defective socket is unclear.

Purpose. The purpose of this systematic review and meta-analysis was to summarize relevant studies within the last 20 years on implant survival and changes in soft and hard tissues after immediate implant placement in esthetic areas with socket defects.

Material and methods. A search was conducted for the relevant studies in the PubMed/Medline, the Cochrane Library, Web of Science, and Embase databases from January 2000 to March 2022. The literature review, data retrieval, and judgment whether the included studies had a risk of bias were handled independently by 2 reviewers, and a single-arm meta-analysis was performed using a statistical software program.

Results. A total of 23 studies evaluating the immediate implant placement of 630 implants (9 studies without a flap and 14 studies with a flap) were included. A 98.1% implant survival rate (95% confidence interval (CI): 96.2%, 100.0%) was determined. Marginal bone loss (MBL) at 6, 12, and ≥24 months were 1.03 mm (95%CI: 1.02, 1.03), 0.72 mm (0.72, 0.73), and 1.15 mm (1.14, 1.16). Gingival recession at 12 months was 0.25 mm (95%CI: 0.17, 0.33). The pink esthetic score (PES) were 12.34 (95%CI: 12.16, 12.52) at 12 months and 12.58 (12.39, 12.76) at ≥24 months.

Conclusions. Current evidence shows that immediate implant placement into defective sockets in esthetic areas is feasible. Immediate implant placement can have a relatively good therapeutic effect in terms of implant survival rate, MBL, gingival recession, and PES. (J Prosthet Dent 2025;133:411-426)

Immediate implant placement (IIP) has become popular as it shortens the duration of therapy and minimizes the number of surgical procedures, with survival rates comparable to those of delayed implant placement.[1–3] Additionally, IIP has been reported to yield excellent clinical outcomes in terms of marginal bone loss (MBL) and pink esthetic score (PES).[4–9]

At the Fifth Consensus Conference of the International Team for Implantology (ITI) in 2013, it was proposed that an intact labial bone wall of at least 1 mm is one of the requirements for IIP.[10,11] However, a thick bone wall phenotype is uncommon in the anterior maxilla, with >1 mm being recorded for only 4.6% of individuals in the central incisor region.[12] Chen and Darby[13] reported that 52% of locations in the maxillary central incisor region had facial bone abnormalities, making an onlay graft followed by delayed implant placement the best option for a patient with a socket defect.[14–17] Buser et al[18] recommended early

Supported by the Natural Science Foundation of Liaoning Province (grant no. 2022-YGJC-08), PR China.
The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Yulong Tang reports financial support was provided by Natural Science Foundation of Liaoning Province. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
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Clinical Implications

Surgical design innovation, implants, and biological bone grafting material improvements have expanded the indications for implant-supported prostheses. Immediate implant placement has become a desired treatment for dentists and patients. Although such placement into defective sockets in the esthetic zone is controversial, it seems that immediate implant placement does not decrease the implant survival rate.

implant placement in conjunction with guided bone regeneration (GBR), flap surgery, and submerged healing following soft tissue healing for patients with a socket defect and a single tooth indicated for extraction in the maxillary anterior region. This recommendation was based on the traditional belief that extraction and IIP in the presence of socket defects may increase the incidence of complications and lead to poor esthetic outcomes.[10] As implant-supported prostheses become more popular, knowledge as to whether immediate implant placement in a defective socket area can have favorable clinical outcomes is needed. Some excellent treatment reports have been published. For instance, even fresh socket defects of 7 mm can be treated with soft tissue and bone tissue transplantation combined with IIP, bringing high initial stability.[19] A study[20] involving 45 patients with socket defects reported that IIP combined with flap surgery, GBR, and an immediate prosthesis was an effective treatment. Moreover, only IIP into socket defects is also feasible, with a reported 100% 10-year survival rate.[21]

The IIP of socket defects in the esthetic area is still controversial, and few relevant studies exist. Therefore, the research hypothesis of the present study was that IIP may be suitable for patients with socket defects in the esthetic area.

MATERIAL AND METHODS

The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) protocol of Page et al[22] was followed in this systematic review. The study was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42022339102). This study did not require ethical approval.

The inclusion criteria primarily followed the participant, intervention, comparison, outcome (PICO) process, including participants who were adults with socket defects in the esthetic zone. The intervention was IIP treatment, and the comparison had no restriction on whether the study had a control group.[23] The outcomes were implant survival rate, MBL, gingival recession, and PES. Moreover, the included studies reported generally healthy participants, a prospective or retrospective research design, a minimum of 5 participants in an IIP group, and at least 12-month follow-up with the definitive prosthesis. Exclusion criteria were the absence of a clear implant method, reviews, editorials, in vitro studies, animal experiments, and expert opinions; studies on the impact of drugs or treatments on bone remodeling; studies on individuals receiving treatments or drugs affecting bone metabolism; studies on implantation affected by tumors; and the unavailability of the required data from the text.

Two independent reviewers (R.C., J.X.) conducted a literature search in the PubMed/Medline, Cochrane Library, Web of Science, and Embase databases from January 2000 to March 2022. The search strategy was ((dental implant) OR (oral implant)) AND ((immediate implant) OR (fresh socket)) AND ((esthetic) OR (anterior teeth) OR (incisor) OR (canine) OR (premolar)) AND ((compromised socket) OR (bone defect) OR (bone deficiency) OR (dehiscence) OR (fenestration)) and varied according to the database, as shown in Table 1.

The eligibility of all studies was independently assessed based on the inclusion and exclusion criteria by 2 reviewers (R.C., J.X.). Initially, the assessment was conducted on the titles and abstracts, and, when studies were selected, kappa coefficients were calculated to measure interrater reliability. Subsequently, eligible studies were read in full and screened. Any disagreements were resolved by discussion with a third reviewer (Y.T.), and data were extracted. For the controlled studies, the data from the IIP groups with socket defects were exclusively analyzed. Characteristic tables were then compiled, and the errors were checked and rectified by the third reviewer (Y.T.).

The quality of each included study was independently evaluated by 2 reviewers (S.W., S.D.), and any discrepancies between them were resolved through discussion. Qualitative assessment for these studies was performed by using the Methodological Index for Nonrandomized Studies (MINORS), including 8 indicators for single-arm studies and 12 for controlled studies. The reliability between reviewers during quality evaluation was assessed by using kappa coefficients. Disagreements were resolved through discussion with a third reviewer (Y.T.). The quality of each controlled study was categorized as high, moderate, or low, based on total scores of 24 to 20, 19 to 14, and <14; the quality of each single-arm study was classified as high, moderate, or low, with total scores of 16 to 12, 12 to 8, and <8.

Data were analyzed using a statistical software program (Stata 17.0; StataCorp LLC). Heterogeneity among studies was expressed using I^2.[24] In an a priori fixed-effects model, the Mantel-Haenszel method was used for dichotomous outcome variables, and effect sizes were represented as risk

Table 1. Search strategies

Database	Search Strategy
PubMed	#1: (dental implant) OR (oral implant) #2: (immediate implant) OR (fresh socket) #3: ((((esthetic) OR (anterior teeth)) OR (incisor)) OR (canine)) OR (premolar) #4: ((((compromised socket) OR (bone defect)) OR (bone deficiency)) #5: (((#1) AND (#2)) AND (#3)) AND (#4)
Web of Science	#1: (TS=(dental implant)) OR TS=(oral implant) #2: (TS=(immediate implant)) OR TS=(fresh socket) #3: ((((TS=(esthetic)) OR TS=(anterior teeth)) OR TS=(incisor)) OR TS=(canine)) OR TS=(premolar) #4: ((TS=(compromised socket)) OR TS=(bone defect)) OR TS=(bone deficiency) #5: #1 AND #2 AND #3 AND #4
Cochrane Library	#1: (dental implant) OR (oral implant) #2: (immediate implant) OR (fresh socket) #3: (esthetic) OR (anterior teeth) OR (incisor) OR (canine) OR (premolar) #4: (compromised socket) OR (bone defect) OR (bone deficiency) #5: #1 AND #2 AND #3 AND #4
Embase	#1: 'dental implant'/exp OR 'dental implant' OR 'oral implant' #2: 'immediate implant' OR 'fresh socket' #3: 'esthetic' OR 'anterior teeth'/exp OR 'anterior teeth' OR 'incisor'/exp OR 'incisor' OR 'canine'/exp OR 'canine' OR 'premolar tooth'/exp OR 'premolar tooth' #4: 'compromised socket' OR 'bone defect'/exp OR 'bone defect' OR 'bone deficiency' OR 'dehiscence'/exp OR 'dehiscence' OR 'fenestration'/exp OR 'fenestration' #5: #1 AND #2 AND #3 AND #4

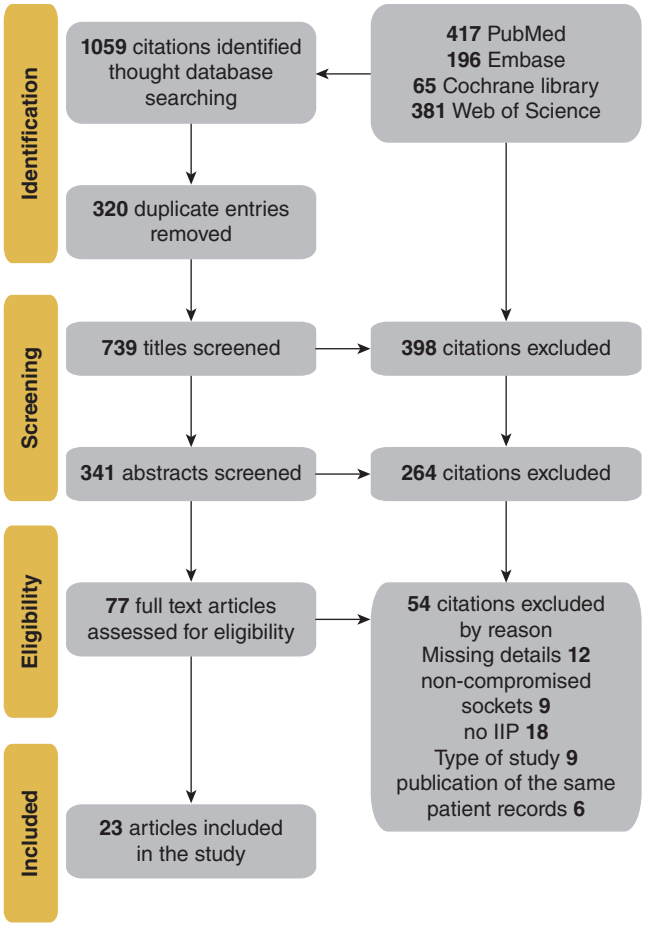

Figure 1. Search strategy. All studies identified by hand-searching reference lists found in database search. For simplicity, number not duplicated in diagram.

ratios (RR) with a 95% confidence interval (CI). For continuous outcome variables, the same approach was used, except that effect sizes were presented as mean differences with a 95% CI. Forest plots were generated to show the effect sizes in the overall and subgroup analyses. The Egger test was used to assess publication bias.

RESULTS

Initially, 1059 studies were retrieved, including 320 duplicates, and 662 studies were excluded based on the titles and abstracts. Interrater reliability for the title in selecting relevant studies was 0.839 ($P<.001$) and abstract 0.787 ($P<.001$). The remaining 77 studies were assessed for inclusion criteria, and the full text of each study was screened. Of these, 54 studies were excluded because of lack of details (12 studies), noncompromised sockets (9 studies), not IIP (18 studies), research type (9 studies), and publication of identical patient treatment (6 studies). Finally, 23 studies were included for data extraction (Fig. 1).[20,25–46]

The characteristics of the included studies are shown in Tables 2 and 3. Eleven controlled[29,33,34,36–38,40–44] and 12 single-arm studies[20,25–28,30–32,35,39,45,46] were included in this study. There were 20 prospective[20,25–28,30–40,42,43,45,46] and 3 retrospective studies.[29,41,44] Ten of the included studies were about IIP and interim restoration placement[25–33,35]; 12 were about IIP with delayed prostheses[20,36–46]; and the remaining 1 was about IIP with immediate and delayed prostheses.[34] In total, 783 participants with a mean age of 44.05 years and 826 implants were evaluated, including 630 IIP implants into socket defects. IIP implants were placed in central incisor locations (n=272), lateral incisor locations (n=121), canine locations (n=39), premolar locations (n=8), or the esthetic zone without a definite tooth location (n=190). The length of the follow-up varied from 12 to 85 months.

The quality assessments of controlled and single-arm studies are shown in Tables 4 and 5. All studies were of

Table 2. Characteristics of included controlled studies

Study (Year)	Type	Socket Condition	Repair Method	Participants	M	F	Age		Implants	Central Incisor	Lateral Incisors	Canine	Premolar	Follow-up	Survival
Pohl et al (2020)	RS	4.95 mm	Immediate	12	4	8	M 11 Ave.50.4		12	7	3	2	0	12	12
		Complete	Immediate	12	7	5	F 13 Ave. 42.5		12	8	4	0	0	12	12
Yang et al (2019)	PS	0-0.5 mm	Immediate	16	8	8	38.31	-	16	14	2	0	0	12	16
		0.5-1 mm	Immediate	14	6	8		-	20	14	2	4	0	12	20
		>1 mm	Immediate	14	10	4		-	14	12	2	0	0	12	14
Slagter et al (2017)	PS	<5 mm	Immediate	20	5	15	39.4	19-70	20	20	7	8	5	12	20
		<5 mm	Delayed	20	8	12	42.3	23-66	19	20	13	6	1	12	20
		≥5 mm	Delayed	20	11	9	43.7	18-63	20	20	12	5	3	12	20
		≥5 mm	Delayed	20	7	13	48.6	20-72	20	20	14	6	0	12	20
Basler et al (2018)	PS	Defect	Delayed	23	11	12	56.6	-	23	-	-	-	-	12	23
Chen et al (2005)	PS	Defect	Delayed	12	3	9	42	-	12	31	17	11	3	24	9
		Defect	Delayed	11	4	7	43.2	-	11					24	11
		Defect	Delayed	13	6	7	40.3	-	13					24	12
		Defect	Delayed	14	9	5	42	-	14					24	12
		Defect	Delayed	12	7	5	41.9	-	12					24	12
Dyakova et al (2020)	PS	Complete	Delayed	21	33	46	-	-	21	-	-	-	-	12	21
		<5 mm	Delayed	23			-	-	23	-	-	-	-	12	23
							-	-		-	-	-	-	12	
		<5 mm Delayed	Delayed	25			-	-	25	-	-	-	-	12	25
Th Elaskary et al (2020)	PS	Complete	Delayed	6	1	11	45.63	-	6	-	-	-	-	13	6
		<5 mm	Delayed	6					6	-	-	-	-	13	6
Fagan et al (2008)	RS	Defect	Delayed	25	10	15	-	25-51	25	-	-	-	-	12	25
		Defect	Delayed	12	8	6	-	26-49	12	-	-	-	-	12	11
Meijer et al (2018)	PS	≥2 mm	Delayed	20	11	9	43.7	18-63	20	12	5	3	0	12	20
		<2 mm	Delayed	20	8	12	42.3	23-66	20	13	6	1	0	12	20
Slagter et al (2021)	PS	8.35 mm	Delayed	20	11	9	44	-	20	12	5	3	0	60	20
		8.65 mm	Delayed	20	7	13	48.6	20-72	20	14	6	0	0	60	20
Takai et al (2017)	RS	Complete	Delayed	4	3	1	42.8	31-56	5	5	1	0	0	85	5
		Defect	Delayed	4	1	3	40.6	25-56	5	3	2	0	0	85	5

Table 3. Characteristics of included single-arm studies

Study (Year)	Type	Socket Condition	Repair Method	Participants	M	F	Age		Implants	Central Incisor	Lateral Incisors	Canine	Premolar	Follow-up	Survival
Kan et al (2007)	PS	Defect	Immediate	23	-	-	39.5	25-63	23	11	10	2	0	12	23
Noelken et al (2018)	PS	Defect	Immediate	20	4	16	47.3	22-76	33	-	-	-	-	60	36
Noelken et al (2011)	PS	All defect	Immediate	16	5	11	43	25-64	18	-	-	-	-	36	17
Noelken et al (2016)	PS	Defect	Immediate	16	8	8	40.9	19-74	20	15	2	3	1	36	20
Rosa et al (2014)	PS	Defect	Immediate	18	10	8	-	24-78	18	11	3	0	4	73	18
Sicilia-Felechosa et al (2020)	PS	8.6 mm	Immediate	40	17	23	58.7	37-80	40	-	-	-	-	84	39
Staas et al (2022)	PS	Defect	Immediate	98	41	57	45.8	17-80	98	75	23	0	0	12	98
Elaskary et al (2021)	PS	Defect	Delayed	20	10	10	45.5	27-59	27	18	9	0	0	24	27
Liu et al (2019)	PS	<10 mm	Delayed	45	21	24	36.7	18-52	45	23	16	6	0	12	45
Wang et al (2021)	PS	<13 mm	Delayed	18	14	4	39.5	20-50	18	-	-	-	-	24	18
Juodzbalys et al (2007)	PS	4.15 mm	Delayed	12	8	4	28	17-49	14	9	5	0	0	12	14
Soliman et al (2014)	PS	Defect	Immediate	14	10	4	36.9	28-45	17	-	-	-	-	14	16

Table 4. Quality assessment for controlled studies

Study (Year)	Aim	Inclusion	Data Collection	Endpoint	Evaluation (Bias)	Follow-up Period	Loss to Follow Up	Sample Size	Control Group	Contemporary Groups	Equivalence	Analysis	Total Score
Pohl et al (2020)	2	2	2	2	0	1	2	2	2	2	2	2	21
Yang et al (2019)	2	2	2	2	0	1	2	2	2	2	2	2	21
Slagter et al (2017)	2	1	2	2	0	1	2	2	2	2	2	2	20
Basler et al (2018)	1	2	2	2	0	2	0	2	2	1	2	1	17
Chen et al (2005)	2	2	1	1	0	1	2	2	2	1	2	2	18
Dyakova et al (2020)	2	1	2	2	0	1	2	2	2	2	2	2	20
Th Elaskary et al (2020)	2	2	2	2	0	2	2	2	1	2	2	2	21
Fagan et al (2008)	2	2	1	1	0	1	2	2	1	2	2	2	18
Meijer et al (2018)	2	2	2	2	0	1	2	2	1	2	2	2	20
Slagter et al (2021)	2	2	2	2	0	2	2	2	1	2	2	2	21
Takai et al (2017)	2	1	2	2	0	2	2	2	2	2	2	2	21

Table 5. Quality assessment for single-arm studies

Study (Year)	Aim	Inclusion	Data Collection	Endpoint	Evaluation (Bias)	Follow-up Period	Loss to Follow Up	Sample Size	Total Score
Kan et al (2007)	2	2	2	2	0	1	2	2	13
Noelken et al (2018)	2	2	2	2	0	2	2	2	14
Noelken et al (2011)	2	2	2	2	0	2	2	2	14
Noelken et al (2016)	2	2	2	2	0	1	2	2	13
Rosa et al (2014)	2	2	1	1	0	2	0	2	10
Sicilia-Felechosa et al (2020)	2	2	2	2	0	2	2	2	14
Staas et al (2022)	2	2	2	2	0	1	2	2	13
Elsdkary et al (2021)	2	2	2	2	0	2	2	2	14
Liu et al (2019)	2	2	2	2	0	1	1	2	12
Wang et al (2021)	2	2	2	2	0	2	2	2	14
Juodzbalys et al (2007)	2	2	2	2	0	1	2	2	13
Soliman et al (2014)	2	2	2	2	0	2	2	2	14

Table 6. Survival of implants

Study (Year)	Implants	Survival
Kan et al (2007)	23	23
Noelken et al (2018)	33	33
Noelken et al (2011)	18	18
Noelken et al (2016)	20	19
Pohl et al (2020)	12	12
Rosa et al (2014)	18	18
Sicilia-Felechosa et al (2020)	40	40
Staas et al (2022)	98	98
Yang et al (2019)	16	16
Slagter et al (2017)	20	20
Slagter et al (2017)	20	20
Slagter et al (2017)	20	20
Soliman et al (2014)	17	16
Basler et al (2018)	23	23
Chen et al (2005)	62	60
Elaskary et al (2021)	27	27
Liu et al (2019)	45	45
Wang et al (2021)	18	18
Juodzbalys et al (2007)	14	14
Dyakova et al (2020)	23	23
Th Elaskary et al (2020)	6	6
Fagan et al (2008)	12	11
Meijer et al (2018)	20	20
Slagter et al (2021)	20	20
Takai et al (2017)	5	5

moderate to high quality. A kappa coefficient of 0.683 ($P<.001$) indicated good interrater agreement in quality assessment.

A total of 25 groups from 23 studies[20,25–46] were considered for analysis (Table 6). Within socket defects, 630 implants were placed between the immediate and delayed prosthesis groups, with 315 implants each. Among these, 16 implants had failed, comprising 5 in the immediate prosthesis group and 11 in the delayed prosthesis group. The overall survival rate was 98.1% (95%CI: 96.2%, 100.0%), exhibiting low heterogeneity (I^2=14.9%, P=.252). The immediate prosthesis group achieved a survival rate of 98.4% (95%CI: 95.7%, 100.0%), also with low heterogeneity (I^2=0.0%, P=.472). Similarly, the delayed prosthesis group recorded a survival rate of 97.9% (95%CI: 96.2%, 100.0%), accompanied by low heterogeneity (I^2=25.6%, P=.172) (Fig. 2).

Tables 7 to 9 provide detailed data on secondary outcomes. Eighteen studies[20,26,28,29,31–36,38–46] reported data on MBL, encompassing a total of 22 groups and 497 implants. The immediate prosthesis group, comprising 8 groups, involved 256 implants, while the delayed prosthesis group, with 14 groups, featured 241 implants. At 6 months, the overall MBL was 1.03 mm (95%CI: 1.02, 1.03) with considerable heterogeneity (I^2=100.0%, $P<.001$), In contrast, the immediate prosthesis group reported an MBL value of 2.52 mm (95%CI: 2.50, 2.54) with considerable heterogeneity (I^2=100.0%, $P<.001$). The delayed prosthesis group displayed an MBL value of 0.94 mm (95%CI: 0.93, 0.94) also accompanied by considerable heterogeneity (I^2=100.0%, $P<.001$) (Fig. 3). At 12 months, the total MBL was 0.72 mm (95%CI: 0.72, 0.73) with considerable heterogeneity (I^2=99.9%, $P<.001$). The value of the immediate prosthesis group

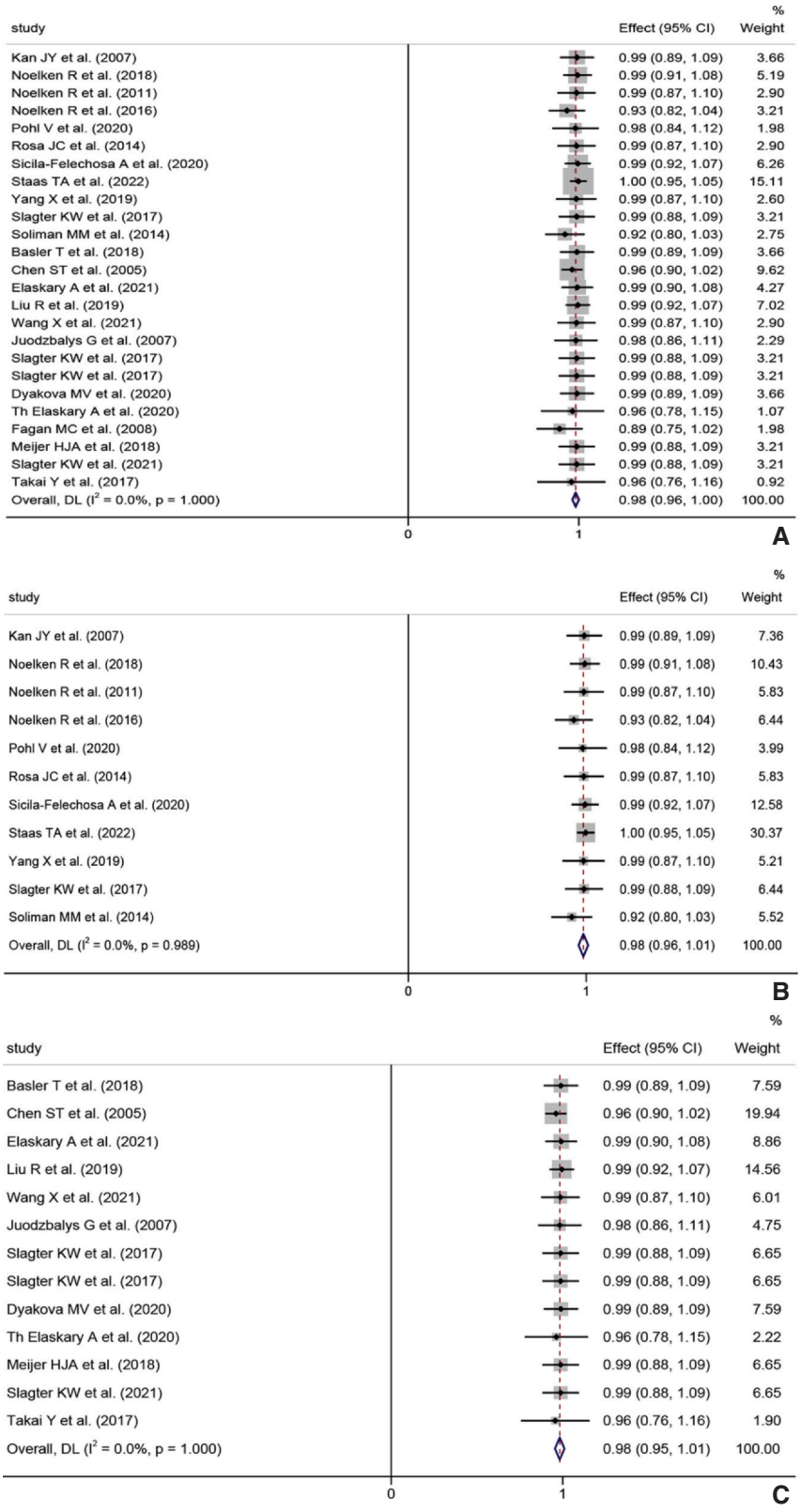

Figure 2. Implant survival rate. Squares on x-axis indicate effect size for each study; bars indicate 95% CI of effect sizes; sizes of squares inversely proportional to respective standard errors. A, Total implant survival rate, 98.1% (95%CI: 96.2%, 100.0%), with low heterogeneity (I^2=14.9%, *P*=.252). B, Immediate prosthesis group, 98.4% (95%CI: 95.7%, 100.0%), with low heterogeneity (I^2=0.0%, *P*=.472). C, Delayed prosthesis group, 97.9% (95%CI: 96.2%, 100.0%), with low heterogeneity (I^2=25.6%, *P*=.172).

Table 7. Marginal bone loss

Study (Year)	n	Pro.	6 m	12 m	≥24 m
Noelken et al (2018)	33	0.74 ±0.85	0.17 ±0.57	0.15 ±0.59	0.04 ±0.65
Noelken et al (2016)	20	0.8 ±0.6	0.2 ±0.6	0.1 ±0.5	0.2 ±0.4
Pohl et al (2020)	12	0.6 ±2.67		1.58 ±2.33	
Sicilia-Felechosa et al (2020)	40	0 ±0	0.47 ±0.7	0.71 ±0.88	0.79 ±0.8
Staas et al (2022)	98	3.1 ±1.2		1.7 ±2.4	
Yang et al (2019)	16	0 ±0	2.18 ±2.03	2.23 ±1.83	
Slagter et al (2017)	20	1.84 ±0.91		1.52 ±0.89	
Slagter et al (2017)	20	1.27 ±0.82		1.28 ±0.85	
Slagter et al (2017)	20	1.01 ±0.55		1 ±0.47	
Basler et al (2018)	11	0.23 ±0.49		0.23 ±0.19	0.19 ±0.21
Basler et al (2018)	12	0.12 ±0.09		0.1 ±0.17	0.16 ±0.1
Dyakova et al (2020)	11	0 ±0	2.07 ±0.05		
Dyakova et al (2020)	12	0 ±0	0.22 ±0.05		
Elsdkary et al (2021)	27	11.68 ±3.31		12.79 ±1.63	12.61 ±1.6
Th Elaskary et al (2020)	6	0 ±0		0.2 ±0.13	
Liu et al (2019)	45	0 ±0	0.96 ±0.51	0.55 ±0.21	
Meijer et al (2018)	20	0 ±0	1.08 ±0.52	1.01 ±0.45	
Slagter et al (2021)	20	0 ±0	1.01 ±0.55	1 ±0.47	0.71 ±0.35
Takai et al (2017)	5	2.02 ±0.36		1.82 ±0.82	3 ±0.36
Wang et al (2021)	18	0 ±0	0.72 ±0.07	0.91 ±0.08	2.92 ±0.19
Juodzbalys et al (2007)	14	0.57 ±0.3	1.72 ±0.72		
Soliman et al (2014)	17	0 ±0	3.91 ±0.17	2.2 ±0.2	

Table 8. Gingival recession

Study (Year)	n	12 m
Pohl et al (2020)	12	0.91 ±0.96
Rosa et al (2014)	18	0.25 ±1.11
Yang et al (2019)	16	0.05 ±0.92
Liu et al (2019)	45	0.59 ±0.71
Meijer et al (2018)	20	0.2 ±0.3
Slagter et al (2021)	20	0.15 ±0.28

Table 9. Pink esthetic score

Study (Year)	n	12 m	24 m
Noelken et al (2018)	33	11.3 ±1.8	11.7 ±2
Noelken et al (2011)	18		12.5 ±1.07
Noelken et al (2016)	20	12.00 ±1.67	11.89 ±1.45
Pohl et al (2020)	12	10.91 ±2.60	
Elsdkary et al (2021)	27	12.67 ±1.27	12.48 ±1.45
Th Elaskary et al (2020)	6	11.33 ±1.37	
Liu et al (2019)	45	10.58 ±2.47	
Wang et al (2021)	18	12.78 ±0.5	12.75 ±0.5
Juodzbalys et al (2007)	14	11.1 ±1.35	

was 1.11 mm (95%CI: 1.09, 1.13) with considerable heterogeneity (I^2=100.0%, P<.001), and the value of the delayed prosthesis group was 0.70 mm (95%CI: 0.69, 0.71) with considerable heterogeneity (I^2=99.9%, P<.001) (Fig. 4). The total MBL after 24 months was 1.15mm (95%CI: 1.14, 1.16), indicating considerable heterogeneity (I^2=100.0%, P<.001). In comparison, the immediate prosthesis group exhibited an MBL value of 0.64 mm (95%CI: 0.61, 0.68), also accompanied by considerable heterogeneity (I^2=99.8%, P<.001). The delayed prosthesis group displayed an MBL value of 1.22 mm (95%CI: 1.21, 1.23), with considerable heterogeneity (I^2=100.0%, P<.001) (Fig. 5).

Six studies[20,29,30,33,42,43] examined gingival recession in 131 implants. The immediate prosthesis group, comprising 46 implants from 3 studies, and the delayed prosthesis group, with 85 implants from 3 studies, were assessed. The total gingival recession at 12 months was 0.25 mm (95%CI: 0.17, 0.33), with substantial heterogeneity (I^2=74.8%, P=.001). The value of the immediate prosthesis group was 0.35 mm (95%CI: 0.07, 0.64) with substantial heterogeneity (I^2=66.3%, P=.052). The delayed prosthesis group was 0.24 mm (95%CI: 0.16, 0.32) with substantial heterogeneity (I^2=85.0%, P=.001) (Fig. 6).

Nine studies[20,26–29,39,40,45,46] evaluated the PES of 193 immediate implants with socket defects. The immediate group comprised 83 implants from 4 studies, and the delayed group involved 110 implants from 5 studies. At 12 months, the overall PES was 12.34 (95%CI: 12.16, 12.52, I^2=88.9%, P<.001), demonstrating substantial heterogeneity. In the immediate prosthesis group, the PES was 11.54 (95%CI: 11.03, 12.06, I^2=16.2%, P=.303), indicating low heterogeneity. The delayed prosthesis group recorded a PES of 12.45 (95%CI: 11.26, 12.65, I^2=92.0%, P<.001), reflecting considerable heterogeneity (Fig. 7). The total PES after 24 months reached 12.58 (95%CI: 12.39, 12.76, I^2=61.5%, P=.035), displaying substantial heterogeneity. Within the immediate prosthesis group, the PES was 12.16 (95%CI: 11.79, 12.61, I^2=40.6%, P=.186), indicating moderate heterogeneity. The delayed prosthesis group had a PES of 12.72(95%CI: 12.50, 12.93, I^2=0.0%, P=.424), showing low heterogeneity (Fig. 8).

According to the Egger test, the survival rate analysis demonstrated publication bias. No evidence of publication bias was found in the other meta-analyses (Table 10).

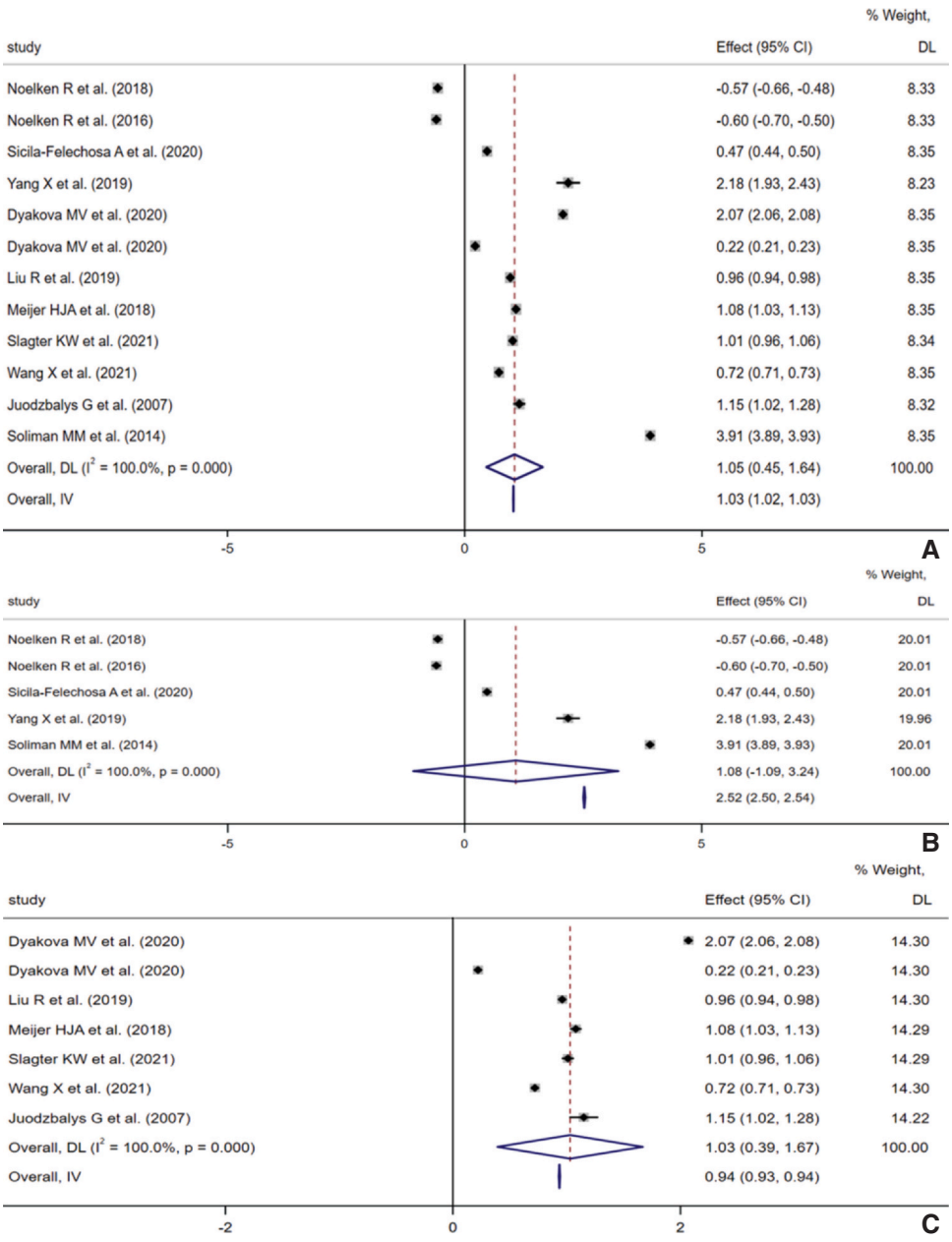

Figure 3. Marginal bone loss at six months. Area of each square proportional to inverse variance of estimate. A, Total marginal bone loss at six months, 1.03 mm (95%CI: 1.02, 1.03), with considerable heterogeneity (I^2=100.0%, *P*<.001). B, Immediate prosthesis group, 2.52 mm (95%CI: 2.50, 2.54) with considerable heterogeneity (I^2=100.0%, *P*<.001). C, Delayed prosthesis group, 0.94 mm (95%CI: 0.93, 0.94) with considerable heterogeneity (I^2=100.0%, *P*<.001).

DISCUSSION

The results of this single-arm meta-analysis supported the research hypothesis that IIP can yield favorable clinical outcomes for patients with socket defects in the esthetic areas. The overall implant survival rate after IIP in socket defects within esthetic areas was 98.1%. A comparison between the immediate prosthesis group and the delayed prosthesis group showed a slightly higher survival rate in the immediate prosthesis group. This trend was consistent with findings from studies on IIP in intact sockets,[1–3,16] a similarity that may be attributed to the presence of sufficient alveolar bone at the tooth root tip in socket defects, ensuring the implants' stability in 3 dimensions and initial stability. During the bone healing, no external forces were applied to disturb the location of the implant, which promoted successful osseointegration and a high survival rate. For instance,

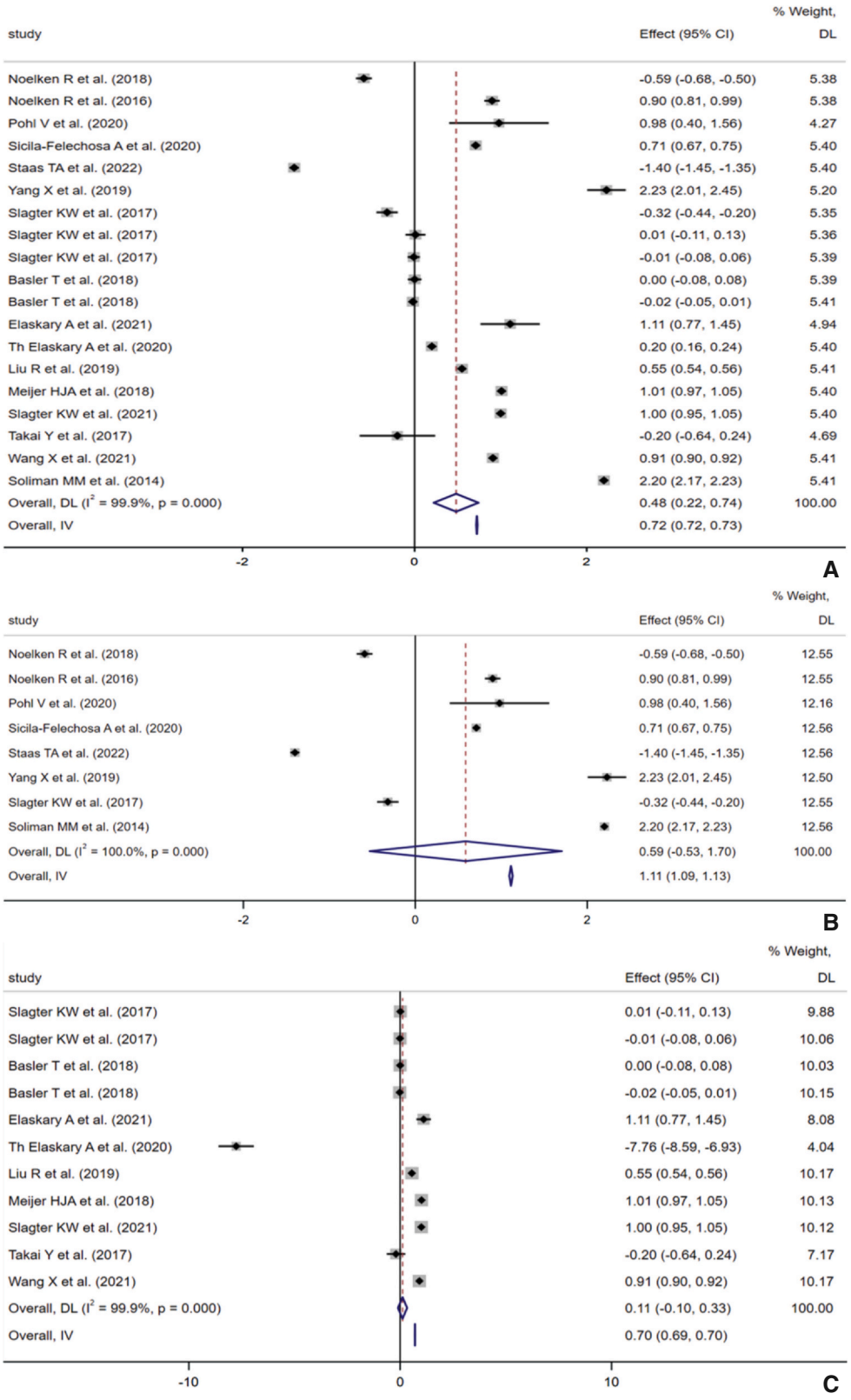

Figure 4. Marginal bone loss at 12 months. Area of each square proportional to inverse variance of estimate. A, Total marginal bone loss at 12 months, 0.72 mm (95%CI: 0.72, 0.73) with considerable heterogeneity (I^2=99.9%, *P*<.001). B, Immediate prosthesis group, 1.11 mm (95%CI: 1.09, 1.13) with considerable heterogeneity (I^2=100.0%, *P*<.001). C, Delayed prosthesis group, 0.70 mm (95%CI: 0.69, 0.70) with considerable heterogeneity (I^2=99.9%, *P*<.001).

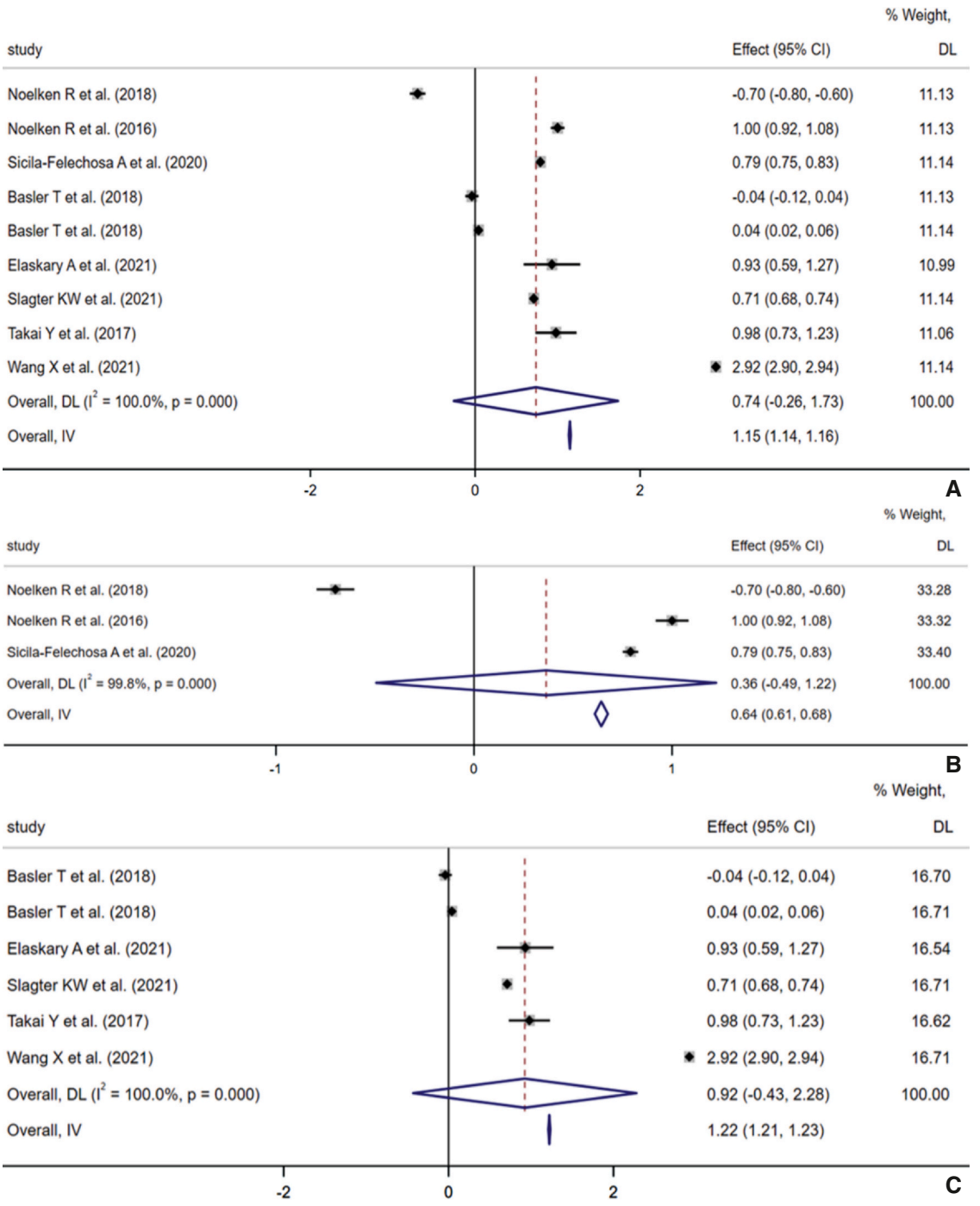

Figure 5. Marginal bone loss at ≥24 months. Area of each square proportional to inverse variance of estimate. A, Total marginal bone loss at ≥24 months, 1.15 mm (95%CI: 1.14, 1.16), with considerable heterogeneity (I^2=100.0%, *P*<.001). B, Immediate prosthesis group, 0.64 mm (95%CI: 0.61, 0.68), with considerable heterogeneity (I^2=99.8%, *P*<.001). C, Delayed prosthesis group, 1.22 mm (95%CI: 1.21, 1.23), with considerable heterogeneity (I^2=100.0%, *P*<.001).

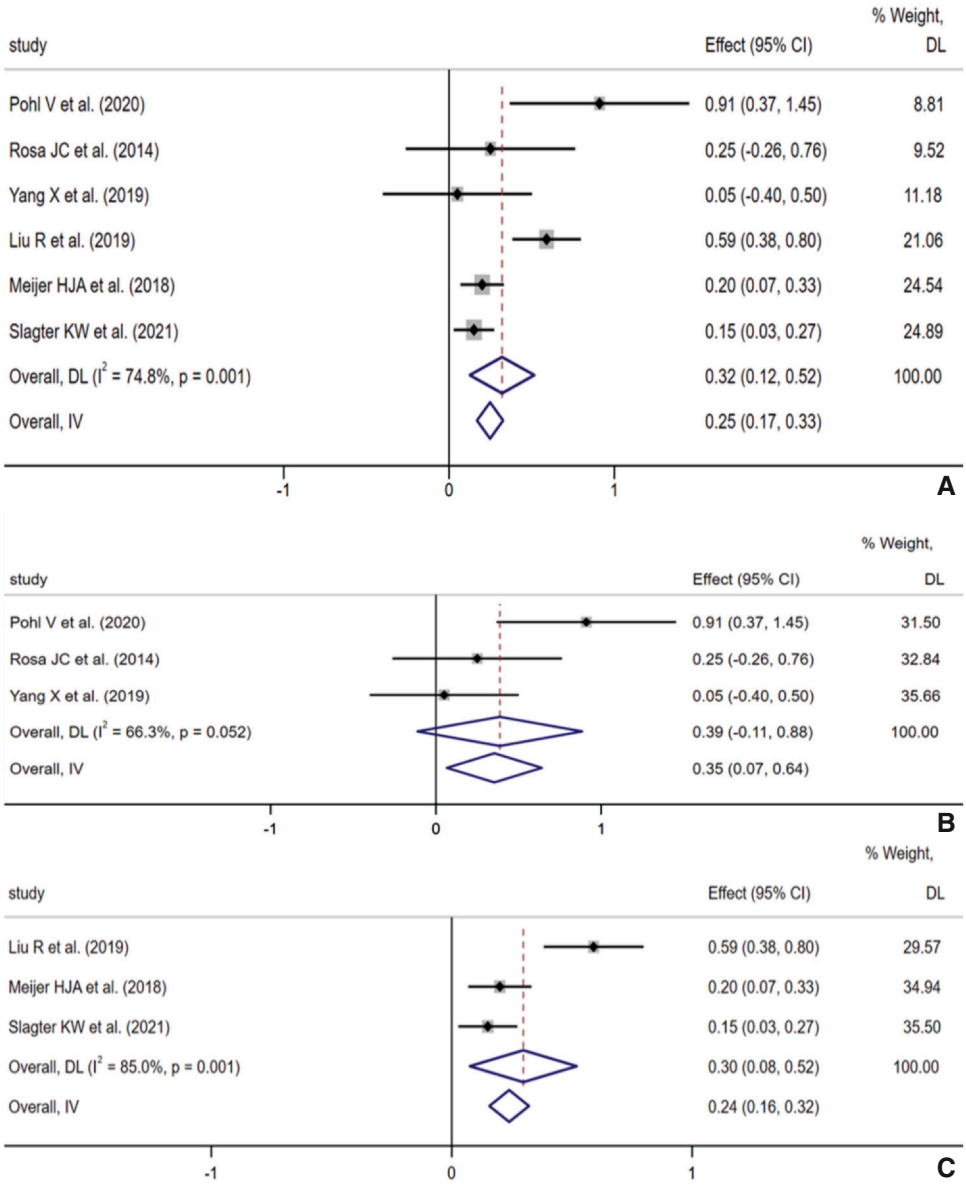

Figure 6. Gingival recession at 12 months. Area of each square proportional to inverse variance of estimate. A, Total gingival recession at 12 months, 0.25 mm (95%CI: 0.17, 0.33) with substantial heterogeneity (I^2=74.8%, *P*=.001). B, Immediate prosthesis group, 0.35 mm (95%CI: 0.07, 0.64) with substantial heterogeneity (I^2=66.3%, *P*=.052). C, Delayed prosthesis group, 0.24 mm (95%CI: 0.16, 0.32) with substantial heterogeneity (I^2=85.0%, *P*=.001).

Takai et al[44] reported a 100% survival rate after an 85-month follow-up.

The cumulative data for MBL in socket defects following IIP at 6, 12, and ≥24 months were 1.03 mm, 0.72 mm and 1.15 mm. Notably, the most significant MBL occurred at 6 months but then stabilized by 12 months, with no further change in alveolar bone levels after 24 months. These results likely stem from factors that include primary wound closure, wound and implant stability, angiogenesis, and space maintenance.[4]

The overall findings regarding gingival recession and PES were positive and consistent with most studies.[5–9] The positive findings could be because IIP surgery, combined with bone augmentation, can reconstruct alveolar bone morphology and height, resulting in improved gingival esthetics with reduced gingival recession. Well-reconstructed alveolar bone provides a secure attachment site for the gingival tissues, contributing to enhanced PES.

Gingival recession appeared to be slightly less in the delayed prosthesis group compared with the immediate group, possibly because the delayed group involved a flap procedure with tight sutures, which could have promoted gingival healing, maturity, and stability, thereby reducing the incidence of gingival recession.

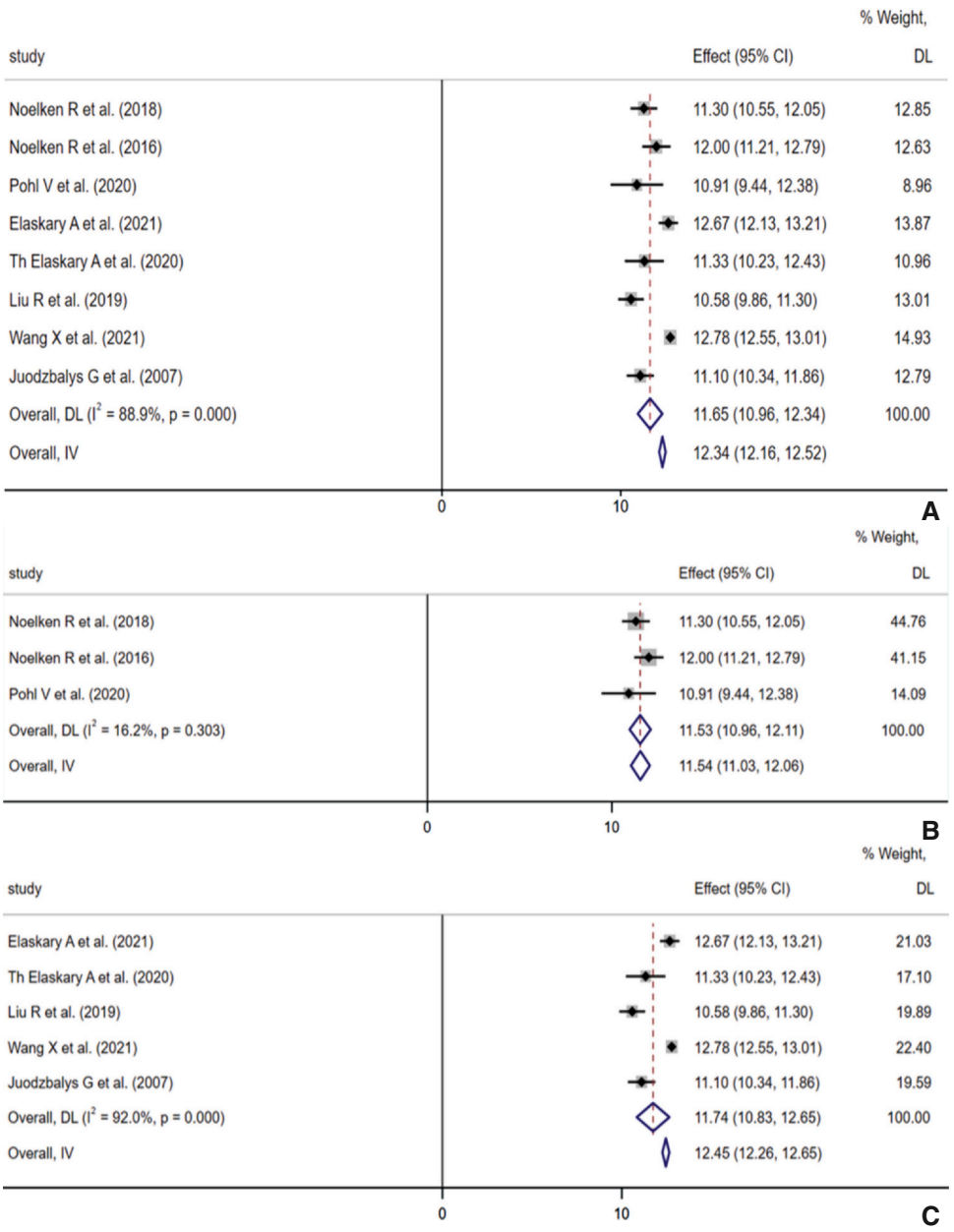

Figure 7. Pink esthetic score (PES) at 12 months. Area of each square proportional to inverse variance of estimate. A, Total PES at 12 months, 12.34 (95%CI: 12.16, 12.52), with substantial heterogeneity (I^2=88.9%, *P*<.001). B, Immediate prosthesis group, 11.54 (95%CI: 11.03, 12.06), with low heterogeneity (I^2=16.2%, *P*=.303). C, Delayed prosthesis group, 12.45 (95%CI: 12.26, 12.65), showing considerable heterogeneity (I^2=92.0%, *P*<.001).

Limitations included that this study was a single-arm meta-analysis, resulting in a low level of evidence because of the limited availability of research on IIP in socket defects within esthetic areas. Future large-scale randomized controlled trials should be conducted, and a standardized classification system for socket defects, measurement methods, and evaluation criteria established. Nevertheless, IIP did offer a promising research direction for addressing socket defects in esthetic areas. These advancements would provide a more dependable and comprehensive theoretical foundation.

The varying biological behavior of different tooth positions could introduce within-study bias in this research. Unfortunately, the included studies did not provide specific statistical analysis results related to tooth position, which prevented an analysis. Recognizing this limitation, future studies should prioritize addressing this issue and conduct a detailed analysis.

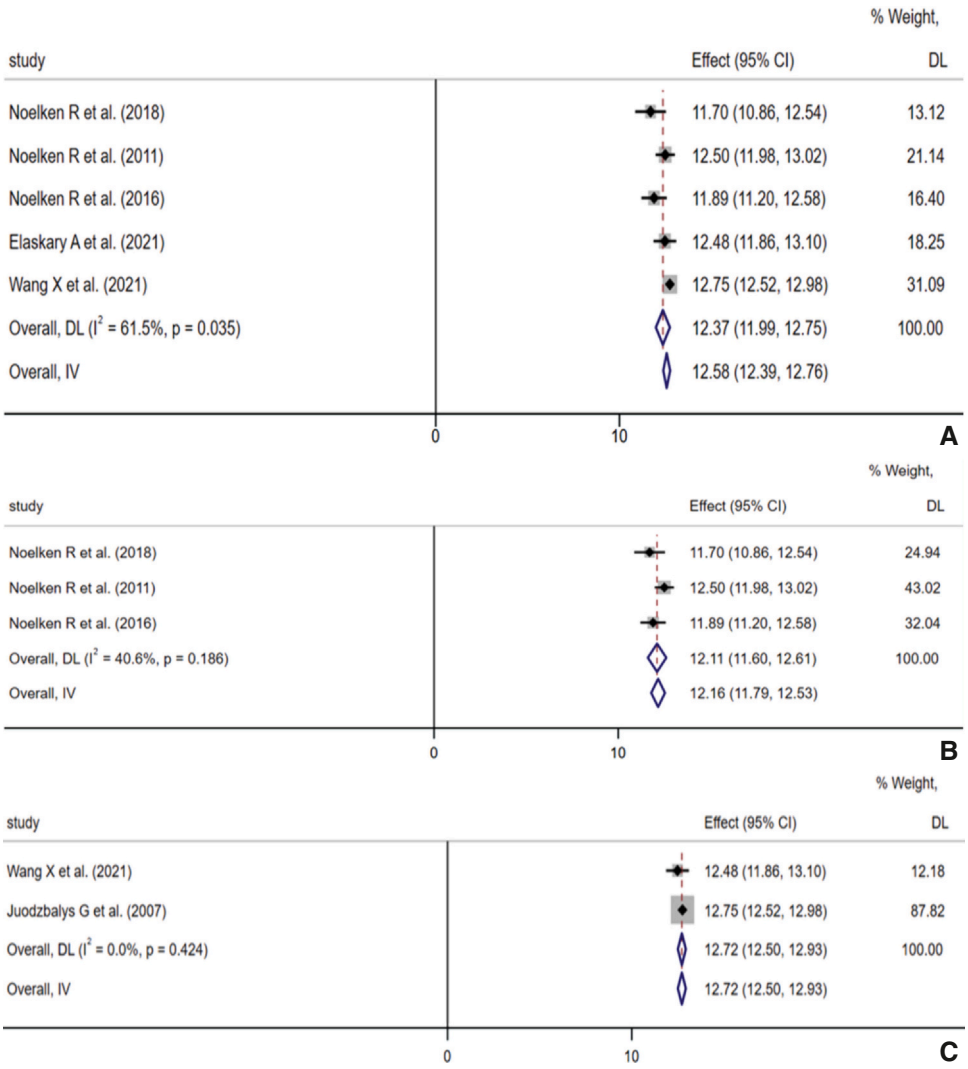

Figure 8. Pink esthetic score (PES) at ≥24 months. Area of each square proportional to inverse variance of estimate. A, Total PES at ≥24 months, 12.58 (95%CI: 12.39, 12.76), with substantial heterogeneity (I^2=61.5%, *P*=.035). B, Immediate prosthesis group, 12.16 (95%CI: 11.79, 12.61), with moderate heterogeneity (I^2=40.6%, *P*=.186). C, Delayed prosthesis group, 12.72 (95%CI: 12.50, 12.93), with low heterogeneity (I^2=0.0%, *P*=.424).

Table 10. Result of Egger test for publication bias in each meta-analysis

Analysis	*P*
implant survival	<.001
MBL (6 m)	.179
MBL (12 m)	.643
MBL (≥24 m)	.035
PES (12 m)	.007
PES (≥24 m)	.036
Gingival recession	.364

MBL, marginal bone loss; PES, pink esthetic score.

CONCLUSIONS

Based on the findings of this systematic review and meta-analysis, the following conclusions were drawn:

1. IIP into socket defects in esthetic areas was feasible. It could lead to positive outcomes regarding the implant survival rate, MBL, gingival recession, and PES.
2. For restorative modalities, both immediate and delayed prostheses had good clinical effects.
3. Further RCTs are needed to establish the safety and efficacy of IIP in socket defects.

REFERENCES

1. Bernal G, Ruiz L, Aellos F, Salazar C, Sadowsky SJ. Clinical and cone beam computed tomography outcomes of maxillary anterior implant restorations after immediate implant placement with interim restorations: A 1- to 14-year retrospective analysis. *J Prosthet Dent* 2023:S0022-3913(23)00362-1. https://doi.org/10.1016/j.prosdent.2023.05.028. Online ahead of print.
2. Gjelvold B, Kisch J, Chrcanovic BR, Albrektsson T, Wennerberg A. Clinical and radiographic outcome following immediate loading and delayed loading of single-tooth implants: Randomized clinical trial. *Clin Implant Dent Relat Res.* 2017;19:549–558.
3. Garcia-Sanchez R, Dopico J, Kalemaj Z, Buti J, Pardo Zamora G, Mardas N. Comparison of clinical outcomes of immediate versus delayed placement of

dental implants: A systematic review and meta-analysis. *Clin Oral Implants Res*. 2022;33:231–277.
4. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. *Int J Oral Maxillofac Implants*. 1986;1:11–25.
5. Atieh MA, Alsabeeha NHM. Soft tissue changes after connective tissue grafts around immediately placed and restored dental implants in the esthetic zone: A systematic review and meta-analysis. *J Esthet Restor Dent*. 2020;32:280–290.
6. Cardaropoli D, De Luca N, Tamagnone L, Leonardi R. Bone and soft tissue modifications in immediate implants versus delayed implants inserted following alveolar ridge preservation: A randomized controlled clinical trial. Part I: Esthetic outcomes. *Int J Periodontics Restorative Dent*. 2022;42:195–202.
7. Atef M, El Barbary A, Dahrous MSE, Zahran AF. Comparison of the soft and hard peri-implant tissue dimensional changes around single immediate implants in the esthetic zone with socket shield technique versus using xenograft: A randomized controlled clinical trial. *Clin Implant Dent Relat Res*. 2021;23:456–465.
8. Groenendijk E, Staas TA, Bronkhorst E, Raghoebar GM, Meijer GJ. Immediate implant placement and provisionalization: Aesthetic outcome 1 year after implant placement. A prospective clinical multicenter study. *Clin Implant Dent Relat Res*. 2020;22:193–200.
9. Pozzi A, Arcuri L, Carosi P, Nardi A, Kan J. Clinical and radiological outcomes of novel digital workflow and dynamic navigation for single-implant immediate loading in aesthetic zone: 1-year prospective case series. *Clin Oral Implants Res*. 2021;32:1397–1410.
10. Chen ST, Buser D. Esthetic outcomes following immediate and early implant placement in the anterior maxilla–A systematic review. *Int J Oral Maxillofac Implants*. 2014;29:186–215.
11. Morton D, Chen ST, Martin WC, Levine RA, Buser D. Consensus statements and recommended clinical procedures regarding optimizing esthetic outcomes in implant dentistry. *Int J Oral Maxillofac Implants*. 2014;29:216–220.
12. Braut V, Bornstein MM, Belser U, Buser D. Thickness of the anterior maxillary facial bone wall-A retrospective radiographic study using cone beam computed tomography. *Int J Periodontics Restorative Dent*. 2011;31:125–131.
13. Chen ST, Darby I. The relationship between facial bone wall defects and dimensional alterations of the ridge following flapless tooth extraction in the anterior maxilla. *Clin Oral Implants Res*. 2017;28:931–937.
14. Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in implant dentistry. *Int J Oral Maxillofac Implants*. 2009;24:237–259.
15. Jensen SS, Terheyden H. Bone augmentation procedures in localized defects in the alveolar ridge: Clinical results with different bone grafts and bone-substitute materials. *Int J Oral Maxillofac Implants*. 2009;24:218–236.
16. Chiapasco M, Casentini P. Horizontal bone-augmentation procedures in implant dentistry: Prosthetically guided regeneration. *Periodontol 2000*. 2018;77:213–240.
17. Cordaro L, Torsello F, Miuccio MT, di Torresanto VM, Eliopoulos D. Mandibular bone harvesting for alveolar reconstruction and implant placement: subjective and objective cross-sectional evaluation of donor and recipient site up to 4 years. *Clin Oral Implants Res*. 2011;22:1320–1326.
18. Buser D, Chappuis V, Belser UC, Chen S. Implant placement post extraction in esthetic single tooth sites: When immediate, when early, when late? *Periodontol 2000*. 2017;73:84–102.
19. Martins da Rosa JC, Fadanelli MA, Zimmerman D, de Oliveira, Rosa ACP. The application of rapid prototyping to improve bone reconstruction in immediate dentoalveolar restoration: A case report. *Int J Esthet Dent*. 2017;12:258–270.
20. Liu R, Yang Z, Tan J, Chen L, Liu H, Yang J. Immediate implant placement for a single anterior maxillary tooth with a facial bone wall defect: A prospective clinical study with a one-year follow-up period. *Clin Implant Dent Relat Res*. 2019;21:1164–1174.
21. Quaranta A, Perrotti V, Putignano A, Malchiodi L, Vozza I, Calvo Guirado JL. Anatomical remodeling of buccal bone plate in 35 premaxillary post-extraction immediately restored single TPS implants: 10-Year radiographic investigation. *Implant Dent*. 2016;25:186–192.
22. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Int J Surg*. 2021;88:105906.
23. Shang Z, Wang M, Zhang B, Wang X, Wanyan P. Clinical translation of stem cell therapy for spinal cord injury still premature: Results from a single-arm meta-analysis based on 62 clinical trials. *BMC Med*. 2022;20:284–302.
24. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ*. 2003;327:557–560.
25. Kan JY, Rungcharassaeng K, Sclar A, Lozada JL. Effects of the facial osseous defect morphology on gingival dynamics after immediate tooth replacement and guided bone regeneration: 1-Year results. *J Oral Maxillofac Surg*. 2007;65:13–19.
26. Noelken R, Moergel M, Kunkel M, Wagner W. Immediate and flapless implant insertion and provisionalization using autogenous bone grafts in the esthetic zone: 5-Year results. *Clin Oral Implants Res*. 2018;29:320–327.
27. Noelken R, Kunkel M, Wagner W. Immediate implant placement and provisionalization after long-axis root fracture and complete loss of the facial bony lamella. *Int J Periodontics Restorative Dent*. 2011;31:175–183.
28. Noelken R, Oberhansl F, Kunkel M, Wagner W. Immediately provisionalized OsseoSpeed(™) Profile implants inserted into extraction sockets: 3-Year results. *Clin Oral Implants Res*. 2016;27:744–749.
29. Pohl V, Fürhauser L, Haas R, Pohl S. Gingival recession behavior with immediate implant placement in the anterior maxilla with buccal dehiscence without additional augmentation-A pilot study. *Clin Oral Investig*. 2020;24:1455–1464.
30. Rosa JC, Rosa AC, Francischone CE, Sotto-Maior BS. Esthetic outcomes and tissue stability of implant placement in compromised sockets following immediate dentoalveolar restoration: Results of a prospective case series at 58 months follow-up. *Int J Periodontics Restorative Dent*. 2014;34:199–208.
31. Sicilia-Felechosa A, Pereira-Fernández A, García-Lareu J, Bernardo-González J, Sicilia-Blanco P, Cuesta-Fernández I. Flapless immediate implant placement and provisionalization in periodontal patients: A retrospective consecutive case-series study of single-tooth sites with dehiscence-type osseous defects. *Clin Oral Implants Res*. 2020;31:229–238.
32. Staas TA, Groenendijk E, Bronkhorst E, Verhamme L, Raghoebar GM, Meijer GJ. Does initial buccal crest thickness affect final buccal crest thickness after flapless immediate implant placement and provisionalization: A prospective cone beam computed tomogram cohort study. *Clin Implant Dent Relat Res*. 2022;24:24–33.
33. Yang X, Zhou T, Zhou N, Man Y. The thickness of labial bone affects the esthetics of immediate implant placement and provisionalization in the esthetic zone: A prospective cohort study. *Clin Implant Dent Relat Res*. 2019;21:482–491.
34. Slagter KW, Raghoebar GM, Bakker NA, Vissink A, Meijer HJ. Buccal bone thickness at dental implants in the aesthetic zone: A 1-year follow-up cone beam computed tomography study. *J Craniomaxillofac Surg*. 2017;45:13–19.
35. Soliman MM, Zaki AA, El Gazaerly HM, Al Shemmrani A, Sorour AEL. Clinical and radiographic evaluation of copolymerized Polylactic/polyglycolic acids as a bone filler in combination with a cellular dermal matrix graft around immediate implants. *Int J Health Sci ((Qassim))*. 2014;8:381–392.
36. Basler T, Naenni N, Schneider D, Hämmerle CHF, Jung RE, Thoma DS. Randomized controlled clinical study assessing two membranes for guided bone regeneration of peri-implant bone defects: 3-Year results. *Clin Oral Implants Res*. 2018;29:499–507.
37. Chen ST, Darby IB, Adams GG, Reynolds EC. A prospective clinical study of bone augmentation techniques at immediate implants. *Clin Oral Implants Res*. 2005;16:176–184.
38. Dyakova MV, Bespalova NA, Klochkov AS, Durnovo EA. Preservation of bone and soft tissue components of the alveolar ridge during immediate implantation in the aesthetic zone of jaws with bone deficiency. *Sovrem Tekhnologii Med*. 2020;12:57–62.
39. Elaskary A, Meabed M, Abd-ElWahab Radi I. Vestibular socket therapy with immediate implant placement for managing compromised fresh extraction sockets: A prospective single-arm clinical study. *Int J Oral Implantol ((Berl))*. 2021;14:307–320.
40. Th Elaskary A, Y Gaweesh Y, Maebed MA, Cho SC, El Tantawi M. A novel method for immediate implant placement in defective fresh extraction sites. *Int J Oral Maxillofac Implants*. 2020;35:799–807.
41. Fagan MC, Owens H, Smaha J, Kao RT. Simultaneous hard and soft tissue augmentation for implants in the esthetic zone: Report of 37 consecutive cases. *J Periodontol*. 2008;79:1782–1788.
42. Meijer HJA, Slagter KW, Vissink A, Raghoebar GM. Buccal bone thickness at dental implants in the maxillary anterior region with large bony defects at time of immediate implant placement: A 1-year cohort study. *Clin Implant Dent Relat Res*. 2019;21:73–79.
43. Slagter KW, Meijer HJA, Hentenaar DFM, Vissink A, Raghoebar GM. Immediate single-tooth implant placement with simultaneous bone augmentation versus delayed implant placement after alveolar ridge preservation in bony defect sites in the esthetic region: A 5-year randomized controlled trial. *J Periodontol*. 2021;92:1738–1748.
44. Takai Y, Ouhara K, Movila A, Kawai T. Retrospective case series analysis to evaluate ridge augmentation procedure applied to immediate implant placement in the esthetic zone: Five-year longitudinal evaluation using cone beam computed tomography. *Int J Periodontics Restorative Dent*. 2017;37:521–530.
45. Wang X, Wang G, Zhao X, Feng Y, Liu H, Li F. Short-term evaluation of guided bone reconstruction with titanium mesh membranes and CGF Membranes in immediate implantation of anterior maxillary tooth. *Biomed Res Int*. 2021;2021:4754078.
46. Juodzbalys G, Wang HL. Soft and hard tissue assessment of immediate implant placement: A case series. *Clin Oral Implants Res*. 2007;18:237–243.

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Acknowledgments
The authors thank Prof Xingshun Qi from the Department of Gastroenterology at the General Hospital of Northern Theater Command (Shenyang, PR China) for his help in interpreting the significance of the current results. The authors also thank Dr Xiangbo Xu and Dr Fei Gao for their assistance with the statistical aspects of our research.

CRediT authorship contribution statement
Rui Chen: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing-original draft, Writing-review and editing. **Jialin Xu:** Methodology, Validation, Formal analysis, Writing-original draft, Writing-review and editing. **Shuang Wang:** Validation, Formal analysis, Data Curation. **Siyi Duan:** Validation, Formal analysis, Data Curation. **Zijian Wang:** Validation, Formal analysis, Data Curation. **Xiaodong Zhang:** Data Curation, Supervision. **Yulong Tang:** Conceptualization, Methodology, Supervision, Writing - review and editing , Funding acquisition.

https://doi.org/10.1016/j.prosdent.2024.02.022