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Research Article

Does Primary Stability is Mandatory for Dental Implant Success? A Systematic Review of Literature

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Abstract

Background: Implant primary stability is considered a prerequisite of implant osseointegration and ultimately, implant success. The prognosis of dental implants installed with low or without primary stability is still unclear. The aim of this systematic review was to assess the survival rate of implants placed with low/without primary stability, and to diagnose risk factors that might affect outcomes of such implants.

Material and methods: Electronic search in the National Library of Medicine (MEDLINE-PubMed) was performed on articles published in English up to September 2020. The terms (MeSH words) used in the search were 'Dental' OR 'Oral' AND 'Implant' AND 'Survival' OR 'Success' AND 'Stability' OR 'Low stability' AND 'Insertion torque'. In addition to the online databases of selected journals. Randomized and controlled clinical trials, cohort studies, case control studies and prospective or retrospective case series were included.

Results: Of the retrieved 386 publications, 24 studies met the inclusion criteria, with a total of 1632 implants, giving survival rate of 96.32%. No statistically significant influence of the type and site of implantation on implant survival was recorded. A significant higher failure rate of immediately loaded implants that than those with delayed loading protocols.

Conclusion: Poor primary stability might not negatively affect the survival rates of non-immediately loaded dental implants.

Keywords: Primary stability; Insertion torque; Zero primary stability; Dental implant success; Dental implant failure.

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Introduction

Absence of implant mobility in the bone bed after placement is a well-known definition for primary stability, which highly depends on mechanical engagement of the threaded implant with the with the surrounding host bone [1].

It is generally accepted that implant stability is a pivotal factor that ensure undisturbed bone healing around dental implant, and subsequently implant osseointegration [2]. For decades, primary stability is considered a prerequisite of implant osseointegration and ultimately, implant success [3-5] and specially for implants installed immediately after tooth extraction [6].

Primary stability is influenced by multiple factors including the materials used, microscopic/macroscopic implant design, the local bone characteristics [7-9], and the surgical technique of implant placement [10].

In situations when low bone quality is encountered, increasing implant primary stability could be achieved using self-tapping or tapered implants, or through modifications of surgical techniques like undersized osteotomy or bone compaction [11]. Other researchers considered elongation of healing period without implant loading to enhance osseointegration process and hence, implant success [5].

Implant stabilities were assessed by different means, but their accuracy was controversial throughout many studies. Resonance frequency analysis (RFA) and the Periotest (PT) are the most popular digital methods. However, they cannot predict implant success upon installation [12]. Other methods are insertion torque (IT) measurement and the clinical assessment of implant stability as described by Rodrigo et al. [13]. The last two methods prevail over others [14].

With the presence of different prosthetic protocols, different values of primary stability are required for successful osseointegration [15]. Thirty (30 n.cm) is considered the least IT needed to maintain successful osseointegration, this idea is highly accepted in many published literature as well as its sufficient to allow both conventional and immediate loading of the implants [16,17]. However, for immediately loaded single implants, authors [18] recommend insertion torque of >35 N.cm or more if important to decrease implant failures. Other studies found an increase in failure rates when implants installed with insertion torques ≤ 25 N.cm [19,20].

FRA indicated low primary stability when ISQ values are ≤ 45. Favorable implant stability is considered when ISQ values ≥65 [21]. When implant primary stability assessed by PT, researchers [22-24] identified values of -5 to -2 are desirable for successful osseointegration.

There are clinical trials evaluated the osseointegration of implants placed with low primary stability in different settings [15,12,25,26]. In this review, authors aimed to evaluate the survival of low or zero primary stability dental implants installed in human jawbones: and factors influencing it such as the time of implantation and loading, host bone qualities, and the different sites of placement.

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Material and Methods

The PICO (patient, intervention, comparison, and outcome) question was "what is the survival rate of dental implants placed with low/without primary stability in partially/completely edentulous patients?" The secondary outcome was the factors that could affect implant survival.

Search strategy

Electronic search in the National Library of Medicine (PubMed) was performed on articles published in English up to September 2020. The terms (MeSH words) used in the search were 'Dental' OR 'Oral' AND 'Implant' AND 'Survival' OR 'Success' AND 'Stability' OR 'Low stability' AND 'Insertion torque'.

In addition, the online databases of the following Journals: Clinical Oral Implants Research, Clinical Implant Dentistry and Related Research, The International Journal of Oral & Maxillofacial Implants, Implant Dentistry, Journal of Oral and Maxillofacial Surgery, Journal of Prosthetic Dentistry. Data sources also included the reference lists of identified articles.

Screening and selection

After the first-round search, the duplicate records were eliminated, then three reviewers (AA, RA, and BT) viewed the title and abstract of each article independently and the full text was downloaded if it was considered relevant to the inclusion criteria of the study which were:

1. Any clinical study (Randomized controlled trials, controlled clinical trials, cohort studies, case control studies and prospective or retrospective case series) reported on endosseous dental implants installed with low/ without primary stability.
2. Studies with a minimum follow-up period of 3 months after implant placement.
3. Studies were also selected if contain data of interest among other findings.
4. No restriction concerning implant micro design, surface modifications, and size.
5. No restriction in respect to site of implantation, local bone quality, surgical technique, time of implantation, loading protocol, and prosthetic design.
6. No restriction regarding patient's habits, periodontal health, and medical status.

A third-round search was carried out using the references of all included articles that met the inclusion criteria. Any dis-agreement between reviewers is solved by consensus.

The following data were extracted from selected clinical studies: Type of study, follow-up period, number of installed implants, number of participants, participant demographics (age and sex), implant size (length, and diameter), site of implant placement, local bone quality, timing of implantation, timing of implant loading, number of failed implants, and implant survival rate.

The primary outcome in this review was the survival rate of implants placed with low/without primary stability. Depending on the sample size of each study, the weighted mean survival rate was calculated.

The secondary outcomes were assessed by calculating the odd ratios to compare the survival rate of those implants with respect

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to implant sites, and timing of implantation and loading.

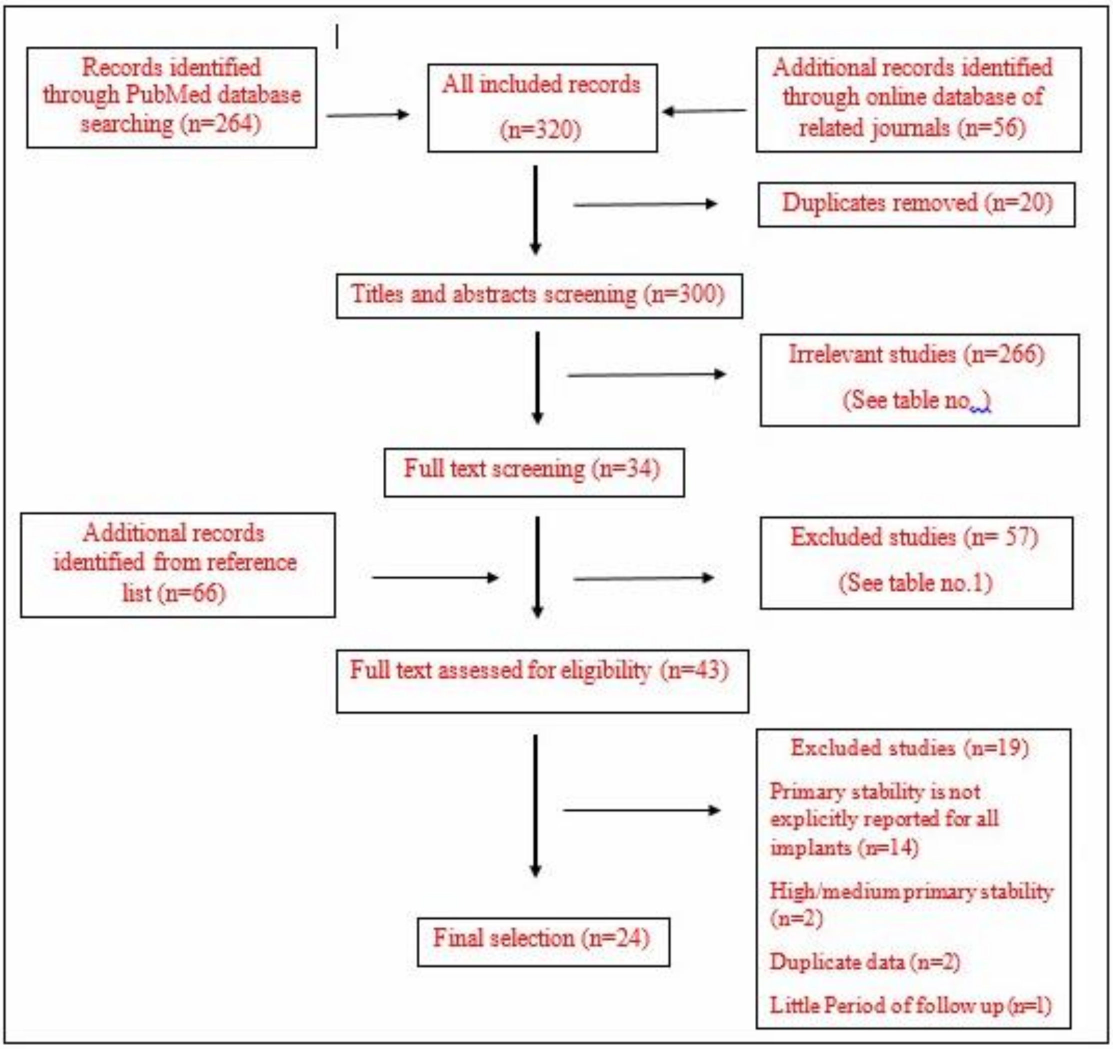

Figure 1: Article selection process.

Results

The first-round online search resulted in 320 potentially relevant articles. Twenty duplicates were identified and eliminated resulting in 300 articles available for titles and abstracts screening. In the first round of evaluation, 34 articles were considered. A review of the reference lists in these articles adding another 66 articles; among them, nine articles seem eligible, giving a total 43 articles available for full text screening as a second round of evaluation.

Only 24 articles met the inclusion criteria [12,13,15,20,27-46] and were suitable for final review. Patients and implant characteristics in addition to the clinical characteristics and outcomes among the selected studies are summarized in Table 1 and 2. The included studies comprised 6 retrospective studies [15,27,28,32,36,44] and 18 prospective studies [12,13,20,29-31,33-35,37-46]; among them; 3 randomised clinical trials [33,38,43] and 1 controlled clinical trial [28].

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Table 1: Patients and Implants Characteristics of Included Studies.

Author (year)		Type of study	Age range (years)	No. of patients/implants	(n) Implant length (mm)	(n) Implant diameter (mm)
Baldi et al (2020)	27	Retrospective	34-81	25/26	(16) 8-10	(10) 3.7
					(3) 11.5	(9) 4.1
					(7) ≥ 13	(7) 4.7
Bianconi et al (2020)	28	Retrospective/controlled	47-73	23/23	NA	NA
Lee KJ et al (2019)	15	Retrospective	19-84	156/ 169	(46) 7-8.5	(10) 3-3.6
					(110) 9-11.5	(34) 3.8-4.5
					(13) >11.5	(119) 4.8-5
						(6) >5
Elian SA (2019)	29	Prospective	NA	14/14	(14) 11.5-16	(14) 3.2-4.3
Faot et al (2019)	30	Prospective	56-74	NA/12	(12) 10	(12) 2.9
Cobo-Vázquez et al (2018)	12	Prospective	NA	NA/92	(92) 3-5	(92) 8-15
Jun et al (2018)	31	prospective	15-68	15/20	NA	NA
Kim et al (2018)	32	Retrospective	NA	NA/10	(10) 6-14	(10) 3.3-4.8
Kronstrom et al (2017)	33	Prospective/randomized	47-61	3/3	(3) ≥ 10	NA
Verardi et al (2017)	34	Prospective	45-82	7/11	(5) 8-10	(5) 4.1
					(6) 12-14	(6) 4.8
Norton MR (2017)	35	Prospective	22-79	21/29	(3) 9	(3) 3.6
					(19) 11-13	(19) 4.2-4.5
					(7) 15-17	(5) 4.8-5
						(2) 5.4
Levin BP (2016)	36	Retrospective	NA	9/10	(10) 10-15	(10) 3-4.8
Jensen and Adams (2014)	37	Prospective	NA	10/13	(13) 10-18	NA
Hof et al (2014)	38	Prospective/	45-86	21/42	(24) 10	(10) 3.5

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		randomized			(18) 13	(31) 4.3
						(1) 5
Degidi et al (2012)	39	Prospective	42-81	13/51	(51) 11-18	3.4-5.5
Barewal et al (2012)	40	Prospective	20-82	20/20	(20) 11-13	(20) 4
Palarie et al (2012)	41	Prospective	NA	NA/47	NA	(47) 3.3-4.7
Rodrigo et al (2010)	13	Prospective	NA	NA/213	NA	NA
Alsaaadi et al (2007)	42	Prospective	18-86	274/682	NA	NA
Testori et al (2007)	43	Prospective/ randomized	NA	NA/7	(7) 8.5-15	(7) 4-6
Balshi et al (2007)	44	Retrospective	29-82	39/44	NA	NA
Marzola et al (2007)	45	Prospective	NA	NA/3	(3) 8.5-15	(3) 4
Ottoni et al (2005)	20	Prospective	18-60	10/10	(10) 10-15	(10) 3.8-4.5
Orenstein et al (1998)	46	Prospective	30-80	81/81	(24) 8-10	(73) 3-4
					(33) 13	(8) >4
					(24) 16	
(n)* = Number of implants, NA= Not available,						

Table 2: Clinical Characteristics and Outcomes of Included Studies.

Author (year)		Follow up period	Stability measurement	Site of Placement (n)*	Bone quality (n)	Type of implantation (n)	Type of loading (n)	Failure (n)	Implant survival (%)
Baldi et al (2020)	27	1 year	IT	Ant. Man. (1)	Soft	Delayed	Delayed	1	96.15
				Ant. Max. (3)					
				Post. Man. (6)					
				Post. Max. (16)					
Bianconi et al (2020)	28	3 years	IT	Post. Man. (9)	NA	Immediate	Delayed	0	100
				Post Max. (14)					
Lee KJ et al (2019)	15	9.28 years	IT	Ant. Man. (2)	D2 (45)		Delayed	7	95.86

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				Ant. Max. (13)	D3 (61)	Delayed+bone graft (43)			
				Post. Man. (57)	D4 (63)				
				Post. Max. (97)					
Elian SA (2019)	29	4 years	Clinical	Max. (14)	NA	Immediate	Delayed	2	85.71
Faot et al. (2019)	30	1 year	IT	Man. (12)	NA	Delayed	Delayed	3	75
Cobo-Vázquez et al (2018)	12	>12 month	Clinical	NA	D1 (20)	Delayed	Delayed	3	96.74
					D2 (21)				
					D4 (51)				
Jun et al (2018)	31	12 months	IT	Ant. Max. (5)	NA	Immediate+bone graft	Delayed	0	100
			ISQ	Post. Man. (8)					
				Post. Max. (7)					
Kim et al (2018)	32	10 years	IT	NA	NA	Delayed	Delayed	2	80
Kronstrom et al (2017)	33	5 years	IT	Ant. Mad. (3)	NA	Delayed	Immediate	0	100
			ISQ						
Verardi et al (2017)	34	18-52 months	IT	NA	D4 (11)	Delayed	Delayed	0	100
Norton MR (2017)	35	1 year	IT	Max. (21)	NA	Immediate (5)	Immediate (8)	0	100
			ISQ	Man. (8)		Delayed (24)	Delayed (21)		
Levin BP (2016)	36	12 weeks	IT	Ant.+premolar Mad. and Max. (10)	NA	Immediate+ bone graft	Delayed	0	100
			ISQ						
Jensen and Adams (2014)	37	1 year	IT	Max. (13)	NA	Delayed	Immediate	0	100
Hof et al (2014)	38	12 months	IT	Ant.+premolar Mad. (42)	NA	Delayed	Delayed	0	100
			ISQ						

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Degidi et al (2012)	39	1 year	IT	NA	NA	Immediate	Delayed	1	98.4
Barewal et al (2012)	40	2 years	IT ISQ	Post. Man. and Post. Max. (20)	All types	Delayed	Early (11) Delayed (9)	1	95
Palarie et al (2012)	41	1 year	IT ISQ PT	NA.	D4 (47)	Delayed	Delayed	1	97.87
Rodrigo et al (2010)	13	6-42 months	Clinical ISQ	NA	NA	NA	Delayed	6	97.18
Alsaaadi et al (2007)	42	6 months	IT	NA	NA	NA	NA	12	98.24
Testori et al (2007)	43	14 months	IT	NA	NA	Delayed	Immediate (3) Early (4)	0	100
Balshi et al (2007)	44	1 year	Clinical	Max. (30) Man. (14)	D3/D4 (44)	Delayed	Immediate (15) Delayed (29)	7	84.1
Marzola et al (2007)	45	1 year	IT	Ant. Man. (3)	NA	Delayed	Immediate	0	100
Ottoni et al (2005)	20	2 years	IT	Ant.+premolar Max. (10)	D2 (7) D3 (3)	Delayed	Immediate	9	10
Orenstein et al (1998)	46	4-8 months	PT	Ant. Man.+ Ant. Max. (39) Post. Man+ Post. Max. (42)	D1 (7) D2 (24) D3 (36) D4 (13) Unknown=1	Delayed	Delayed	5	93.83
(n)*=Number of implants, NA=Not available, IT=Insertion torque, ISQ=Implant stability quotient, PT=Perio test									
Ant.=Anterior, Post.=Posterior, Man.=Mandible, Max.=Maxilla									

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Sixteen of included studied used delayed type of implantation [12,15,20,27,30,32-34, 37,38,40,41,43-46] compared with five studies used immediate implantation [28,29,31,36,39], and one study [35] used both protocols. Two studies did not report the type of implantation [13,42].

Regarding implant loading protocols, most of included studies used the delayed one [12, 13,15,27-32,34-36,38-41,44,46]. Six studies used the immediate loading [20,33-35,37,45]. Only two studies used early loading of some of implants included in these studies [40,43]. For the site of implantation, ten studies were considered for the lower jaw [15,27,28,30,31,33,35,38,44,45] and nine studies for the upper jaw [15,20,27-29,31,35,37,44].

In the Studies of this review, implant primary stability was measured by periotest values [41,46], insertion torque [15,20,27,28,30-41,45], implant stability quotient values [13,31,33,35,36,38,40,41], or clinically classified [12,13,29,44] according to Rodrigo et al. [13].

Lee et al. investigated the effect of advance surgeries on the survival rate of low stability implant. In their study, 169 implants were evaluated. Eighty-two of them were implanted with advanced surgeries like guided bone generation, bone graft, bone compaction, or sinus lifting. Seven implants were failed, all belongs to advance surgery group, with a significant difference (P=0.005) from implants installed by simple surgeries. Moreover, they recorded size and the design of prosthetic reconstruction over the failed implants. Five of failed implants were 1-unit fixed dental prosthesis (FDP), one implant in 2-unit FDP, and another implant in 4-unit FDP. This result did not exhibit a consistent differences in terms of the implant survival rate (P=0.369). Meanwhile, the size of implants used in their study varied from 3-5mm in diameter, and 7-12mm in length. All of failed implants were ranged from 4.5-5mm in diameter and 8-12 mm in length.

Three studies [15,31,36] evaluated the fate of implant with bone grafting. They installed 43, 20, 10 implants with a survival rates of 88%, 100%, and 100% respectively. While other studies reported the type of material and surface treatment of failed implants, Verardi et al. [34] reported 100% success of eleven sandblasted, acid-etched (SLA) implants. Hof et al. [38] recorded the same success rate when they implanted 42 machined and anodized surface dental implants. However, 5 out 81 implants failed; according to Orenstein et al. [46]; and were commercially pure titanium and titanium alloy implants.

Testori et al. [43] and Barewal et al. [40] considered early loading of 15 low stability implants and get a survival rate of 100% after a follow up period one and two years respectively. Verardi et al. [34] evaluated the survival rate of 11 tissue-level implants installed with very low insertion torque. All implants were survived after two years of loading.

Articles studied the effect of low primary stability on implants installed in D4 bone quality [12,15,34,35,41]. 96.7%. of 183 implants were survived 1-9 years after loading. Authors encountered lack of primary stability during implant insertion [12,13,29,44]. They evaluated the prognosis of 171 implants. One hundred seventy-one implants. Eighteen implants were failed, giving a survival rate of 89.5%.

The total number of installed implants with low primary stability in the included studies

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was 1632. Sixty implants failed, giving a survival rate of 96.32%. Both genders were included in this review, and the number of participants was 741 as reported in the 17 of the included studies (53.3% female, 46.7% male).

Although there is a higher survival rate of low stability implants placed immediately after tooth extraction compared with delayed implantation, however, no significant difference (P=0.201) was found between the two groups. Similarly, no consistent difference was recorded in the pooled survival of implants installed in the maxilla versus mandible (P=0.11), or anterior versus posterior region (P=0.29).

With regard to the type of implant loading, a significantly (P=0.005) higher failure rate of implants that immediately loaded than those with delayed loading protocols. The delayed loading of low stability implants exhibited six times greater survival than immediate loading protocol (Table 3).

Table 3: Survival Rate of Low Stability Implants.

Intervention	Study groups (n)	Installed implants (n)	Failed implants (n)	Survival rate% Mean (SD)	P-value	Odd ratio
Immediate Implantation	6	123	3	97.56 (5.74)	0.201	2.7
Delayed Implantation	17	614	39	93.65 (21.9)		
Immediate loading	6	44	9	79.55 (36.74)	0.005	6.79
Delayed Loading	16	850	31	96.35 (7.97)		
Maxilla	9	243	19	92.18 (30.74)	0.111	1.53
Mandible	10	165	8	95.15 (8.28)		
Anterior	5	50	2	96 (1.10)	0.29	1
Posterior	4	100	4	96 (2.57)		

Despite the difference in sample size and follow up period, and other implant and clinical characteristics of the included studies, ten studies [28,31,33-38,43,45] showed a survival rate of 100% for low stability implants, more than 93% in nine studies [12,13,15,27,39-42, 46], 75-85% in four studies [29,30,32,44]. Conversely, Ottoni et al. [20] recorded very low survival rate of 10%.

Discussion

Absence of implant mobility after its placement in the bone is the exact definition describes primary stability and reflecting the mechanical engagement between implant and bone. On the contrary, secondary stability is the progressive increase in stability related to biological phenomenon occurred at the bone-to-implant interface resulting in a new bone formation and remodeling [47]. Osseointegration is the result of healing that takes place around dental implant and can be defined as a direct intimate contact between the implant and surrounding bone. It dependent on many factors, like the host response, the implant surface characteristics, and the loading protocols [48].

Understanding the healing process, which maintains the implant in the bone bed long

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standing is substantial for all professionals and implantologist. Simunek A et al. [49] claims that mechanical stability decreases during the early stages of healing and upsurges of biological stability. This idea was remarkably cleared in many research. A period of three weeks after implant placement is dignified to be the least stable time argument where stress relaxation of the bone takes place along with remodeling that result in a loss of primary stability [50] and progressive increase in the secondary stability as new bone formation and remodeling occur [47]. Implants are in great risk of micromotion throughout the transition period between primary and secondary stability; can end with consequent failure [41]. Patil and Bharadwaj [48,51] and Fawad et al. [52] in their systematic reviews highlighting the importance of primary stability as a predictable parameter for the long-term success of dental implant. In spite of this demonstrated positive impact of good primary stability on implant survival, Rodrigo et al. [13] achieved high survival rate (97.2%) of 231 unstable dental implants, which is comparable to the primary stable implants evaluated in other studies [53-55].

Throughout more than 300 reviewed articles, authors show the need for high degree of mechanical stability for successful osseointegration. The question, which should asked here; what is the fate of dental implant when installed with low or zero stability?; this is the exact aim of this review. Articles that discuss the low primary stability are limited to about 10% of our retrieved studies.

Mandibular implants reported to have higher survival rates when compared to maxillary implants with specification to posterior sides as stated by Jemt et al. [56,57]. This logically related to anatomical and physiological differences in bone quality between two jaws with thinner compact bone available in posterior maxilla while thick trabecular mandibular bone [58,59]. This may be the cause behind higher survival rate of low stability mandibular implants as reported in this review.

Soft bone clinically defined as poor bone mineralization with limited bone resistance [58,60]. Low-density bone was mainly found in the posterior maxillae and in recent extraction sites of the alveolar ridge [34] Authors [61,62] conclude those higher failure rates are shown for the implant seated in soft bone. Turkyilmaz et al. [10] and Miyamoto et al. [63] confirm in their clinical study the availability of strong correlation between implant stability and bone density. In contrast to the previous studies, additional studies in the posterior mandible showed high failure rates due to the poor bone quality as well as other additional factors [64,65].

In this review, 15 of included studies did not gave details about the quality of implant bone bed, as the under estimation of such point in low primary stability implants may change the proper conclusion. However, three studies [15,36,38] reported high survival rate of 96-100% for the delayed loaded low stability implants installed in soft bones. This may be attributed to the use of self-tapping implants [36] or due to the use of rough surface implant [15,36] as suggested by researchers [66,67] depending on their histomorphometric studies when they observed that implants with a rough surface (sand blasted acid etched or hydroxyapatite-coated implants) significantly enhanced the amount of implant-to-bone contact compared with a

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smooth surface implant. It is worth to know that implants with low primary stability may acquire osseointegration even with a soft bone if their surface is highly osteoconductive [34,68,69].

Balshi et al. [44] demonstrated a lower success rate of turned surface low stability implants (70%) than implants unstable rough surface implants (92%). Similarly, Orenstein et al. [46] achieved higher success rate (100%) of unstable implants with hydroxylapatite coating when compared to implants without coating (81.5%).

Lee et al. [15] reported a failure of 5 out of 43 low stability implants placed simultaneously with bone regenerative procedures. They claimed that this failure owing to the associated co-morbidities such as inflammation that may result in loss of osseointegration. Digidi and his colleagues [39] showed that implants without good primary stability can successfully osseointegrated even when immediately loaded if splinted to other implants with good primary stability. Other researchers [70,71] in order to reduce their micro movement and consequently the risk of early failure also high lightened the rigid connection of low stability implants.

In the current study, two articles [40,43] evaluated the fate of 15 implants with early loading protocols. All implants were survived after 14 months of loading. These studies confirmed that implants in any type of bone could be successfully early loaded after 6 weeks of implantation in spite of their low insertion torque. The use of rough surface implants may stand before this behavior. This point was proved by other randomised clinical trial [72] that demonstrates an acceptable survival rate for early loading regardless the type of bone bed.

In a review study published by Reza et al. 2017 [73] stated that "The implants with little initial stability show an increase of stability during the healing process. On the contrary, the stability decreases during the healing process in implants with high initial stability" keeping the implant with no primary stability has a high chance of integrating similar to the ones with good primary stability [74]. This point can be authorized with the result of this review as low stability implant show high success rate.

Researchers point that the absence of implant stability may result in harmful micro-movements during the healing period [75,76] especially with functionally loaded implants [77-79] with a movement exceed 150 μm which result in fibrous tissue formation around implants instead of osseointegration [15]. This point was highlighted in many studies [80-82]. The lowest survival among the included studies was recorded by Ottoni et al. [20] where 9 of 10 implants failed when placed with insertion torque of 20 N.cm and immediately loaded with provisional crown designed to receive occlusal load. They claimed that the existence of both micro and macro movements can induce peri-implant fibrous tissue formation. The pooled result of this review showed a significant difference in success rate between different loading protocols favoring delayed loading. The difference in survival rate may be related attributed to the difference in implant surfaces [15] or in the amount of occlusal load.

To conclude, lack of implant primary stability may not consider a risk factor resulting in implant failure. Such implants can successfully osseointegrated, especially for osseo-conductive rough surface

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implants that kept with low micromotion during healing phase. More prospective studies are needed to follow a larger number of unstable implants for a longer period in different clinical conditions.

Ethical Approval

This study follows the Declaration of Helsinki; US Federal Policy for the Protection of Human Subjects and No need for specific ethical approval as its systematic review.

Author Contributions

Authors are contributed to acquisition, statistical analysis and interpretation of data, drafted the manuscript and critically revised the manuscript for important intellectual content. Authors gave final approval and agreed to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of Interest

The authors report no conflicts of interest related to this review.

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