review

PROGNOSIS OF SHORT IMPLANTS IN ORAL REHABILITATION: WHERE DO WE STAND TODAY?

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SUMMARY

Objective. The purpose of this review is to evaluate the long-term prognosis of short-length implants (≤ 6 mm) placed in the posterior maxilla and to review their clinical, radiographic and patient-reported outcomes based on prospective randomized controlled trials.

Materials and methods. An electronic MEDLINE (PubMed) search was conducted to identify randomized clinical trials comparing short implants (≤ 6 mm) to longer implants (≥ 6 mm) placed in the posterior maxilla with or without sinus elevation procedures. The studies that did not meet the inclusion criteria were eliminated. Patient, implant and prosthesis information were filled/gathered in tables and a systematic review was performed on the clinical, radiographic and patient reported outcomes.

Results. Eight RCTs were selected for the study and a total of 409 short implants placed in 260 patients and 422 longer (≥ 6 mm) implants in 252 patients were analyzed. Out of all these included implants, 20 short and 8 long were lost after 3 to 5-year follow-up. Both groups showed high survival rates ranging between 86.7% and 100% for group short and between 95.6% and 100% for group long. Biological complications mainly occurred in group long where augmentation procedures were performed. The short implant group showed more favorable outcomes in terms of PROM levels, post-operative morbidity as well as surgical time and cost.

Conclusion. The findings of the present systematic review suggest that short implants may be considered a promising option/alternative for posterior maxilla rehabilitation especially in elderly or medically compromised patients where augmentation procedures should be avoided or at least simplified.

Key words: short dental implants, survival rate, C/I ratio, marginal bone loss, complications.

Introduction

For decades now, implants have been considered the most reliable and effective solution for the rehabilitation of partially or completely edentulous jaws (1). Implant survival rate is affected by systemic (diabetes, osteoporosis, smoking habits…) and local factors (implant length, residual bone height, bone quality…) (2). In the posterior maxilla, unfavorable type IV bone density and reduced bone volume (mainly due to maxillary sinus pneumatization and/or apical resorption of the ridge) may hinder optimal implant placement. In order to overcome these challenges, various procedures such as sinus floor elevation (lateral or transcrestal) were used to allow standard length implant placement. Although these techniques are associated with high survival rates, they present equally important drawbacks: longer surgical and healing time, increased morbidity and higher complication risk (3). This led to the introduction of short implants as an alternative and less invasive solution for replacing missing teeth. The defini-

tion of short implants had widely varied and their length had continuously decreased over the years. Recently, a consensus definition considered every implant with an intra-bony length of 6 mm or less as short (4). Even though this treatment option presents various advantages including lower surgical time, lower cost and reduced patient morbidity, its long-term survival rate remains uncertain (5). In the past, implant machined-surface led to high failure rates notably in the posterior maxilla and especially with short implants (6). Recently, and with the development of new engineered surfaces, many publications have concluded that short implants present survival rates similar to those of standard length implants (7-9).
The aim of this review is to assess the long-term prognosis of short-length implants placed in the posterior maxilla and to review their clinical, radiographic and patient-reported outcomes based on prospective randomized controlled trials.

Materials and methods

An electronic MEDLINE (PubMed) search was conducted for randomized controlled clinical trials published from January 1, 2013 up to December 31, 2018. The search key words were used as follows:

- "Posterior Maxilla" OR "Atrophic posterior maxilla"
- "Short implant" OR "reduced length implant" OR "6-mm length implant" OR "less than 6-mm length implant"
- "Sinus lift" OR "Sinus floor elevation" OR "augmentation"
- "Posterior maxilla" AND "Short implant"
- "Survival Rate"
- "PROM"

Inclusion criteria:

- Prospective randomized clinical trials
- Short implants with ≤ 6 mm intra-bony length
- Implant rehabilitation in partially edentulous posterior maxilla (single-tooth gaps included)
- Follow-up of at least 3 years post-loading.

Exclusion criteria:

- Case reports, case series, retrospective, in-vitro or preclinical studies.
- Short implant length > 6 mm
- Implant rehabilitation of edentulous posterior mandible
- Studies not meeting all the other inclusion criteria
- Duplicate studies (only the last published were included).

The studies that did not fulfill the inclusion and exclusion criteria were eliminated. Patient, implant and prosthesis information were gathered in tables and a systematic review was performed on the clinical, radiographic and patient reported outcomes.

Results

The electronic search identified a total of 176 articles. After applying the inclusion and exclusion criteria, 8 RCTs were found eligible for the study. In total, 260 patients were rehabilitated with 409 short implants and 252 patients with 422 longer ones. Two studies placed implants in the posterior maxilla only (10, 11); whereas, the other six RCTs placed implants in both posterior jaws. Four studies presented outcomes after a follow-up of three years (11-14), three other studies had a 5-year observation period (10, 15, 16) and one study reported outcomes after ten years (17). The length of short implants was fixed to ≤ 6 mm (intra-bony length) in all included RCTs; whereas, the length of longer implants varied between 8.5 and 15 mm. Three studies placed short and standard length implants in non-augmented sites (13, 16, 17), four other studies placed long implants in grafted sites (10-12, 14) and one study placed standard length implants with, if needed, an internal sinus lift (15). All three studies with 5-year follow-up period evaluated single-crown implants (10, 15, 16), one study with 3-year observation period placed, as required, single or splinted crowns (12) and the other four studies placed splinted adjacent implants (Tables 1, 2).

Table 1 - Information on implants and reconstructions in the included studies ("-" not reported).

RCT	Implant system	Group	Implant length & diameter (mm)	Imp Nb	Loading protocol	FU (yr)	Prosthesis (Design, Connection, Retention)
Thoma et al. (2018) (10)	Astratech, Osseo-Speed	GL: One-stage lateral sinus lift	L: 11, 13 or 15 Ø: 4	64	6 months	5	-Fixed -Single -Switching Platform -Screw-retained or cemented
		GS: Short implant	L: 6 Ø: 4	60			
Naenni et al. (2018) (15)	Strauman, SLActive (tissue level)	GL: Standard length implant (with internal sinus lift if needed)	L: 10 Ø: 4.1	FU-5: 46	10 weeks	5	-Fixed -Single -Screw-retained -Torque 35 Ncm
		GS: Short implant	L: 6 Ø: 4.1	FU5: 40			
Rossi et al. (2016) (16)	Strauman, SLA	GL: Standard length implant	L: 10 Ø: 4.1	Ba: 30	7 weeks	5	-Fixed -Single -Made with gold-palladium alloy & porcelain
		GS: Short implant	L: 6 Ø: 4.1	Ba: 30			
Gastaldi et al. (2018) (12)	Megagen, Xpeed	GL: One-stage lateral sinus lift (piezosurgery)	L: 10, 11.5, 13 or 15 Ø: 5	37	4 months	3	-Fixed -Single or Splinted -External hexagon -Screw-retained or cemented
		GS: Short implant	L: 5 Ø: 5	36			
Zadeh et al. (2018) (13)	Astratech, Osseo-Speed	GL: Without grafting	L: 11 Ø: 4	101	6 weeks	3	-Fixed -Splinted -Screw-retained -Diff angulations -Internal connection -Torque 15 Ncm
		GS: Short implant	L: 6 Ø: 4	108			
Esposito et al. (2014) (14)	MegaGen, EZ Plus	GL: Two-stage lateral sinus lift (implant placement after 4 months)	L: 10, 11.5 or 13 Ø: 4	38 (-1 pt)	6 months	3	-Fixed -Splinted -Internal connection -Screw-retained
	MegaGen, Rescue	GS: Short implant	L: 5 Ø: 6	34 (-1 pt)			
Bechara et al. (2017) (11)	MegaGen, AnyRidge	GL: One-stage lateral sinus lift	L: 10, 11.5, 13 or 15 Ø: 4-8	43	4 months	3	-Fixed -Single (45) or Partial (45) -Internal conical hexagon
		GS: Short implant	L: 6 Ø: 4-8	44			
Storelli et al. (2018) (17)	Strauman, SLA	GL: No grafting	L: 10 Ø: 4.1	-	8 weeks	10	-Fixed -Cemented -SynOcta Abutment (35 Ncm)
		GS: Short implant	L: 6 Ø: 4.1	-			

Table 2 - Patient characteristics of the included studies ("-": not reported).

RCT	Group	Nb of imp	Patient						
			Nb	Sex	Age	Smoking	Periodontitis	Bruxism	Other
Thoma et al. (2018) (10)	GL	BA: 70 FU-5: 64	BA: 51 FU-5: 46	51 +/- 12.8	F: 23 M: 28	Hab: 6 Occ: 7 Ex: 15 No: 23	-	-	-
	GS	Ba: 67 FU-5: 60	BA: 50 FU-5: 44	50 +/- 14.05	F: 29 M: 21	Hab: 8 Occ: 0 Ex: 10 No:32	-	-	-
Naenni et al. (2018) (15)	GL	FU-5: 46 (22 maxilla)	FU-5: 46	M: 39 F: 47	57	Hab: 10 (between 10 &20 cig/day)	14	-	-
	GS	FU-5: 40 (12 maxilla)	FU-5: 40		56	Hab: 11	22	-	-
Rossi et al. (2016) (16)	GL	BA 30 FU-5: 29	BA 30 (12 max)	M: 16 F: 14	48.4	6 smokers	-	-	-
	GS	BA 30 FU-5: 26	BA 30 (15 max)	M: 16 F: 14	47.7	7 smokers	-	-	-
Gastaldi et al. (2018) (12)	GL	Ba: 68 FU-3: 66	Ba: 37 FU-3: 37	F: 23 M: 14 Max	55.6	6 pts	-	-	-
	GS	Ba: 68 FU-3: 66	Ba: 40 FU-3: 39	F: 32 M: 8	69.8	7 pts	-	-	-
Zadeh et al. (2018) (13)	GL	Ba: 101 FU-3: 88	BA:46 FU-3: 40	M: 27 (59%) F: 19 (41%)	54.1 (SD 10)	Non 33 (72%) Ex: 8 (17%) Occ: 2 (4%) Hab: 3 (7%)	7	3	Abnormal Jaw: 8 Dentigerous cyst: 1
	GS	Ba: 108 FU-3: 98	Ba:49 FU-3: 46	M: 21 (43%) F: 28 (57%)	54.8 (SD 9.3)	Non: 29 (59%) Ex: 17 (35%) Occ: 1 (2%) Hab: 2 (4%)	12	3	Abnormal jaw: 5 Horiz& sag overbite & occlusive erosive tooth wear: 3
Esposito et al. (2014) (14)	GL	BA: 68 FU-3: less than 66	BA: 30 FU-3: 26	56	4 moderate 1 heavy	NR	-	-	-

To be continued →

Continued from Table 2

	GS	BA: 60 FU-3: less than 55	BA: 30 FU-3: 25	56	4 moderate 1 heavy				
Bechara et al. (2017) (11)	GL	Ba: 45 FU-3: 43	Ba: 20 FU-3: 19	M:9 F:11	49.5 +/- 13.4	8 smokers 12 non smokers	9 history of periodontal		
	GS	Ba: 45 FU-3: 44	Ba: 33 FU-3: 32	M: 10 F: 23	47.5 +/- 16.2 yrs	7 smokers 26 non smokers	9 history of periodontal		
Storelli et al. (2018) (17)	GL	Ba: 28 (7 maxilla) FU-10: 20 (5 maxilla)	Ba: 11 FU-10: 9	F: 5 M: 4	65	4 light 1 ex	-	-	-
	GS	Ba: 26 (5 maxilla) FU-10: 20 (5 maxilla)	BA 13 FU-10: 8	F: 5 M: 3	62	2 light 1 ex	-	-	-

Implant SR

In general, oral implants are associated with high survival rates ranging from 86.7% (16) to 100 % (11) in group short and from 95.6% (11) to 100% (10) in group long. In fact, out of the 422 long and 409 short implants included in this review, 8 long and 20 short were lost in both jaws (11 out of the 20 short implants lost were located in the posterior maxilla).

The four included studies with 3-year follow-up concluded no significant difference in survival rates between short and long implants. Three of these studies reported more failures in group short, while on the other hand, the study of Bechara et al. (2017) (11) reported zero losses in group "short" *versus* two in group "long" (failed due to chronic sinus infection).

The analyzed studies with 5-year follow-up reported a higher failure rate in group short. However, this difference only reached significance in one study (15) with four short and zero longer implants lost (91% survival rate of short implants). After 10 years of loading, Storelli et al. (2018) (17) concluded no significant difference in survival rates with only one short implant lost.

Marginal bone level (MBL)

All the RCTs selected in this review evaluated marginal bone level (MBL) changes at scheduled follow-up time-points. Overall, mean MBL changes ranged from 0.14 mm (16) to 1.34 mm (12) for short implants and from 0.15 mm (15) to 1.75 mm (12) for longer ones.

At the 3-year follow-up, three out of four studies reported a significant difference in MBL changes in favor of short implants (11, 13, 14). Similarly, in a 5-year follow-up study comparing the outcomes of 6 mm short *versus* 10 mm single-crown implants placed in the posterior jaws, Rossi et al. (2016) (16) concluded signif-

icantly higher bone loss around standard length implants. On the other hand, two other studies with the same follow-up period (10, 15) detected greater loss around short implants; yet these findings did not reach significance. After 10 years of loading, the difference in MBL in favor of group long turned out to be insignificant (17).

Crown to implant ratio

Most of the studies evaluated crown to implant ratio (C/I) (10, 13, 15-17) and concluded a higher quotient for short implants (≤ 6 mm) varying between 1.55 (16) and 1.86 (10). The corresponding values for longer implants ranged from 0.93 (13) and 1.04 (15). Thus, the difference between the two groups was found to be statistically significant.

Biological complications

Biological complications related to implant therapy may be encountered during or after surgery. The most common intra-operative and post-operative complications found in the analyzed studies were Schneiderian membrane perforation and peri-implant mucositis, respectively.
From a total of 409 short and 422 longer implants, 12 intra-operative (3 short and 9 standard length implants) and 45 post-operative biological complications (9 short and 36 standard length implants) occurred during the respective follow-up periods. In other words, 2.93% short implants and 10.66% longer implants were affected by biological complications.
However, only one study (11) reported a significant difference between the 2 groups with zero complication in group short and 19 in longer implants placed with simultaneous lateral sinus lift procedure. Of these 19 complications: 3 were intra-operative (bleeding) and 16 were immediate post-operative (pain, swelling, chronic sinus infection). On the other hand, Naenni et al. (2018) (15) did not report any complication for any of the groups after 5 years of function.

Prosthetic complications

None the studies included in this review showed statistical differences in prosthetic complications between the two groups. However, one study (17) reported a significantly higher retention complication rate in short implants after ten-year follow-up (6 decementations in group short *versus* zero in group long). In two of the analyzed studies (11, 16), no prosthetic complications were mentioned after 3 and 5 years in function respectively. One study (15) reported a low number of minor complications (screw loosening/ minor chipping…) that were easily resolved chair-side.
Out of the 831 implants evaluated in this review, 57 short and 35 long were affected by prosthetic complications (screw loosening, abutment or screw fracture, veneer chipping, prosthesis fracture…) resulting in a high prosthetic survival rate with no statistical difference between the 2 groups.

Patient-reported outcome measures (PROM)

Only 3 out of 8 studies took patient-reported outcome measures (PROM) into consideration. Esposito et al. (2014) (14) specified that at 1-month post-loading there was no significant preference between the two procedures. In the same way, Bechara et al. (2017) (11) reported that after three years, patients were highly satisfied with the esthetic and functional outcomes of both treatment options even though the cost was significantly higher in the standard implant group.
Furthermore, a longitudinal study by Thoma,

Haas and Hammerle (10) assessed PROM using the OHIP-49 questionnaire at all treatment and follow-up appointments. The scores at suture removal revealed that both procedures affected the quality of life in terms of physical and functional limitations. However, the subsequent change in PROM severity scores detected in group graft proved that one stage sinus lift had a more considerable influence on quality of life.
After 5 years of function, both groups showed high satisfaction levels with scores even higher than those recorded at baseline.

Surgical time & costs

Thoma et al. (2018) (10) and Bechara et al. (2017) (11) are the only two included studies that took surgery cost and duration into account when comparing short posterior maxilla implants to longer ones placed with one-stage lateral sinus lift procedures. The augmentation procedure significantly increased both surgical time and cost by 40% and 100% respectively (Tables 3, 4).

Discussion

The aim of this systematic review was to assess the long-term clinical performance of short-length implants in the atrophic posterior maxilla. The 8 RCTs included in this review compared short (≤6 mm) implants to longer ones placed in augmented or non-augmented sites in posterior edentulous jaws (Figure 1).
The findings of this review revealed after a follow-up of 3 to 10 years:

a) High survival rate for both groups
b) Higher failure rate in short implant group
c) Significantly higher crown to implant ratio (C/I) in short ≤ 6 mm implants (however, C/I never exceeded 2)
d) No significant difference in marginal bone loss between the two groups
e) More significant biological complications in longer implants (mainly related to the augmentation procedures)
f) No statistical difference in prosthetic complications (although short implants may present higher retention complications)
g) PROM, surgical time & cost in favor of short implants.

Even though the majority of the included RCTs reported a higher survival rate in favor of longer implants, Naenni et al. (2018) (15) is the only included study that concluded a significant difference with 91% survival rate in "short implant" group compared to 100% in "long implant" group. In a recently published RCT (18) that focused on short 6-mm moderately-rough implants, a similar survival rate (91.7%) was found after 10 years in function with 3 implants lost: 2 before loading and 1 after 7 years in function (due to peri-implantitis).
Correlation between implant length and success/survival rate is yet to be firmly established. Some articles reported that short implants exhibit higher failure rates (5, 6, 19); whereas, numerous other studies concluded that both treatment options achieved similar results (9, 20-23).
Survival rate assessment can not be solely based on implant length. Other surgical (initial implant stability, bone quality), prosthetic (C/I ratio, occlusal loads), implant related (diameter, surface topography) as well as systemic factors (smoking, diabetes) should be equally accounted for (22, 24).
In this review, the high C/I was not found to have direct impact on survival rate, MBL or biological complications. In fact, longer implants, especially those placed in augmented sites, were found to have higher crestal bone loss and more biological complications. However, two RCTs (10, 17) speculated that the reported prosthetic complications may have been related to the high C/I ratio. These findings are consistent with the results of a systematic review conducted by Quaranta et al. in 2014 (25). More recently, a consensus study (26) demonstrated that this hy-

Table 3 - Clinical, radiographic and patient reported outcomes ("-" : not reported; "X": not analyzed).

RCT	Imp SR (%)	Prost SR (%)	MBLoss (mm)	C/I Ratio	Intra-op compl	Post-op bio compl	Post-op prost compl		PROM	Cost & Time (min)
Thoma et al. (2018)	100	-	Imp: 0.45 +/- 0.91 Pt: 0.46 +/- 1	0.99 +/- 0.17	0	-50 % mucositis -2% peri-implantitis (BoP +MB loss>2mm)	14 Pt: 30.4%	Loosening/fracture of screw Chipping of ceramic decementation	*Loading: GG<GS *FU: Scores ↗ : No SD between the groups *OHIP-49: -GS: 3 -GG: 5	1946 E 74.6 min
	98.5 imp 98% pt	-	Imp: 0.45 +/- 0.79 Pt: 0.54 +/- 0.87	1.86 +/- 0.23	0	-40.9% mucositis - 0% peri-implantitis - 1 lost	21 Pt: 47.7%			941 E 52.6 min
Naenni et al. (2018)	*100%*	-	-0.15	*1.04*	-	0	- (low nb)		X	X
	91%	-	-0.29	*1.75*	-	-4 lost (just 1 maxillary-premolar) (pain & implant loosening - no peri-implant bone loss)	- (low nb)		X	X
Rossi et al. (2016)	96.7%		0.18	0.97	-	1 lost (first year)	-		X	X
	86.7%		0.14	1.55	-	4 lost (1 max before loading, 2nd and third year: 1 max& 1 mand), 1 max 4th year	-		X	X
Gastaldi et al. (2018)	100	100	1.79 (1.16;1.70)	X	5 mb perfo	0 max Mand:2 long lost, 1 hemorrhage, 1 perforation, 14 paresthesia	1 chipping of the prosthetic lining		X	X
	97	97	1.34 (0.86;1.22)	X	0	1 max implant lost (3 months post loading) 1 mand after 2 years 8 paresthesia (mand)	2 prosthetic screws loosening 1 prosth failed 1 chipping		X	X
Zadeh et al. (2018)	96.2	-	*0.44 (loss 0.02 +/- 0.76)*	*0.93*	0	-1 Removed - 4.9 % mucositis - 1.2% peri-implantitis	7 prosthesis/screw loosening 0 def screw fracture 2 abutment fractures 2 prov prosth fracture 1 def prosth fracture		X	X

To be continued →

Continued from Table 3

	99	-	*0.27 (gain 0.04 +/- 0.43)*	*1.78*	0	-4 implant mobile removed -1.1% mucositis -0 peri-implantitis	3 prosthesis/screw loosening 3 def screw fracture 5 abutment fractures 1 prov prosth fracture 0 def prosth fracture	X	X
Esposito et al. (2014)	97% 2 failed (1 in maxilla)	100	*1.54*	X	1 mb perfo	2 imp failed (1 in maxilla) Mand: 11 paresthesia 1 dehiscence	0	X	X
	92% 5 failed (3 in maxilla)	2 failed	*1.02*	X	3 mb perfo	1 mucositis 5 failed (3 in maxilla) Mand: 3 abscess 3 paresthesia	2 prosthesis lost (1 max & 1 mand) Mand: 3 abutment loosening	X	X
Bechara et al. (2017)	Pt: 95% Imp: 95.6%	-	*0.27*	X	3 bleeding	2 lost 4x11.5 mm (2 mo after placement) (same pt: smoker/ periodontal disease/chronic sinus infection →graft loss) 1 pt pain+swelling 14 swelling	0	High (esthetic & function)	32.2 +/- 8.5 mins 1322 +/- 490 Euro for 1 implant
	Pt & Imp: 100%	-	0.20	X	0	0	0	High (esthetic & function)	19.1 +/- 7.1 min 700 Eur for 1 implant
Storelli et al. (2018)	NR 100%	100	0.37 (bone level 3.14 with 2.8 neck)	1.02 (Romeo FU 5y)	0	5 bio comp 6 pt mucositis	6 technical compl (not severe) (chipping) *2 retention compl (screw loosening)*	X	X
	NR 1 implant lost	89.5%	0.84 (bone level 3.26 with 2.8 neck)	1.64 (Romeo FU 5y)	0	1 lost 2 pt mucositis 2 bio comp	9 Technical complications (not severe) (chipping) *6 retention comp (decementation)*	X	X

pothesis is irrelevant as long as this ratio is within 0.9 and 2.2 (Figure 2).

In a 10-year follow-up study, Rossi et al. (2018) (18) reported 0.8 mm of crestal bone loss around short 6 mm implants. He detailed that half of this loss occurred during the first two years alone, whereas 0.2 mm were lost during the last 5 years. This further underlines the findings of a

Table 4 - Results of the included studies.

RCT	Implant length & diameter (mm)	Follow-up (year)	Results
Thoma et al. (2018)	L: 11, 13 or 15 Ø: 4 L: 6 Ø: 4	5	-No SD: survival rate (SR), MBL changes, PROM (FU-5) and complications -SD: C/I -Both treatments are convenient
Naenni et al. (2018)	L: 10 Ø: 4.1 L: 6 Ø: 4.1	5	-SD: C/I ratio, SR (GS lower than GL) (but no SD between jaws) -No SD: MBL and other clinical parameters -No correlation between the high C/I and MBL changes or technical and biological complications -6-mm single implants: acceptable alternative
Rossi et al. (2016)	L: 10 Ø: 4.1 L: 6 Ø: 4.1	5	-Higher degree of implant loss in GS -C/I remained stable during the FU period -No technical complications reported -SD: MBL (in favor of GS even though both groups reported losses)
Gastaldi et al. (2018)	L: 10, 11.5, 13 or 15 Ø: 5 L: 5 Ø: 5	3	-No SD: SR, prosthesis failure, MBL (even though GL showed more bone loss) -Both groups show similar outcomes -Short implants: preferable option because less treatment time, cost and morbidity
Zadeh et al. (2018)	L: 11 Ø: 4 L: 6 Ø: 4	3	-No SD: cumulative SR, BOP, probing depths and plaque -SD: MBL (in favor of short implants), C/I ratio -Both treatment options presented similar good results
Esposito et al. (2014)	L: 10, 11.5 or 13 Ø: 4 L: 5 Ø: 6	3	-No SD: SR, biological/prosthetic complications -SD: MBL changes (GS losing less bone) -Both treatment options presented similar acceptable results
Bechara et al. (2017)	L: 10, 11.5, 13 or 15 Ø: 4-8 L: 6 Ø: 4-8	3	-No SD: SR -SD: ISQ levels at 3 years (GL stability>GS), MBL (in favor of GS), surgical time & cost (in favor of GS), biological complications -High patient satisfaction in both groups -Similar clinical results, however, short implants present a more favorable option (less time and cost)
Storelli et al. (2018)	L: 10 Ø: 4.1 L: 6 Ø: 4.1	10	-No SD: SR, MBL, prosthesis survival rate, bio & technical complications (6 mm: 8%; 10 mm: 12.5%) -SD: C/I Ratio, retention complications (decementation) -Both treatment options presented similar good results -Bias: limited sample

consensus study by Alberktsson & Zarb (1986) (27) claiming that an average of (≤) 1.5 mm of peri-implant bone is lost during the first year and afterwards, a maximum of 0.2 mm per year. However, this data was obtained with conventional implant designs (machined surface and external implant-abutment connection). Nowadays, considerably better outcomes are achieved with new innovative implant designs (moderately-rough surface topography, platform switching

Figure 1
Panoramic radiograph of the upper left jaw showing the impact of post-extraction sinus pneumatization and apical ridge resorption on residual bone height.

and cone-morse connection, neck architecture: microthreads, microgrooves).
In addition to that, it must be highlighted that peri-implant bone loss is more problematic around short implants because of their reduced length (13). For instance, 0.8 mm of bone loss may go unnoticed around long implants yet meanwhile it represents 13.3 % of the overall 6-mm implant length.
Short implants face additional drawbacks when placed in the posterior maxilla considering the low bone density, the bigger functional loads (multiplied by 300) as well as the more important crown length. That is why researchers previously focused on placing the longest implant possible so that forces will be distributed on a larger implant surface. In an attempt to prove that force dissipation is independent from implant length, finite element analysis (FEA) studies (28-30), have demonstrated that loads are mainly concentrated in the crestal region of an implant.
Since then, numerous parameters were modified in order to create a better biomechanical scenario for short implants.
a) Implant diameter:
It is speculated that a large diameter will reduce the stress on the crestal region (23). In fact, every 1 mm of implant diameter increases the functional contact surface by 30% to 200% (31). A consensus statement by Jung et al. (2018) (4) declared that short implants should be associated with a diameter of 4 mm at least.
b) Implant surface:
Previous machined-surface short implants were found to have low resistance to marginal bone

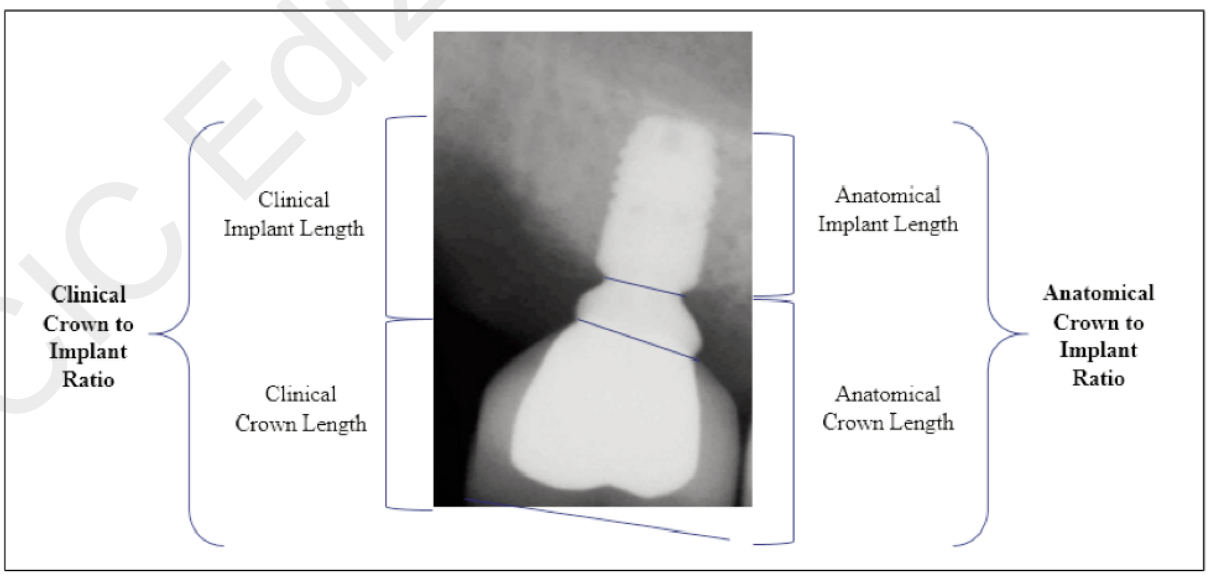

Figure 2
Clinical and anatomical crown to implant ratio.

loss (32, 33) which is why implant systems have shifted to moderately rough surfaces for better osseointegration (34-36) and higher survival rate, especially in poor bone qualities (22, 37, 38). All the RCTs analyzed in this review are in accordance with these findings.

c) Implant neck design:

Coronal microthreads, coronal microgrooves and platform switching connection were found to present an increased horizontal contact length that helps accommodate the biological width. In addition to that, these designs minimize the concentration of axial and non-axial forces in the crestal region which in turn leads to less marginal bone loss (Figure 3).

d) Splinting:

Short implant placement in the resorbed posterior maxilla with high functional loads is in itself an indication for splinting crowns (39). In such cases, the functional loads will be evenly distributed between the implants leading to less stress concentration in the surrounding bone (40).

Besides clinical and radiographic parameters, factors such as PROM, surgery time and cost (initial price and maintenance costs) have become essential when assessing outcomes of different treatment options. In this review, all patients showed high satisfaction levels after a follow-up period of 3 to 5 years. It must be noted that PROM levels are closely connected to the clinical condition of the implant and peri-implant environment (10).

Concerning surgery duration, the results of the included studies are in agreement with the literature data suggesting that a higher surgery time is associated with more complications (41). In fact, more intra- and post-operative biological complications were noted in patients that underwent longer surgical interventions mainly those including augmentation procedures (Figure 4).

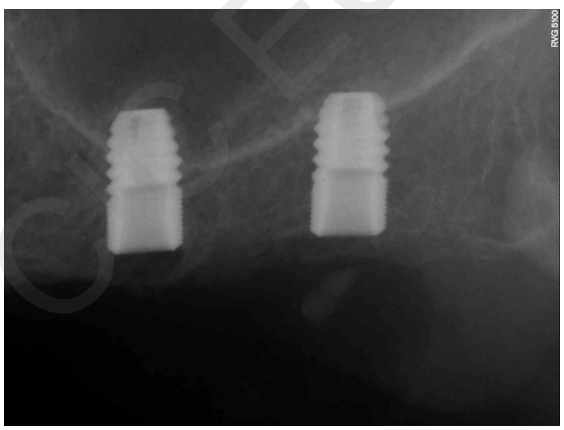

Figure 3
Intraoral radiograph showing two short implants placed in the posterior maxilla. Note the coronal microthreads at the neck region of the implants.

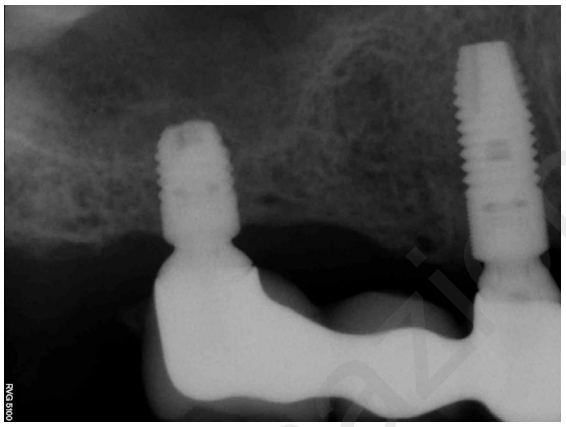

Figure 4
Periapical radiograph showing a maxillary short implant used as distal abutment of a 3-unit bridge.

Conclusion

The findings of the present systematic review suggest that short implants may be considered a promising therapeutic option for posterior maxilla rehabilitation especially in elderly or medically compromised patients where augmentation procedures should be avoided or at least simplified. In such cases, it is essential to consider a treatment option that minimizes surgical trauma and reduces the risk of post-operative complications, such as short or narrow implants. Furthermore, practitioners must devote particular attention to the new concept of “stress-mini-

mizing surgery" as a major factor affecting their therapeutic decision.

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