High-fluoride toothpaste: a multicenter randomized controlled trial in adults

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CLINICAL ORAL IMPLANTS RESEARCH

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Implant survival in 1- versus 2-implant mandibular overdentures: a systematic review and meta-analysis

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Key words: dental implants, implant-retained overdentures, meta–analysis, overdentures, single implant, systematic review, unsplinted attachments

Abstract

Objective: This systematic review was performed to compare the survival of 1- vs. 2-implant overdentures (IODs) in the edentulous mandible.

Materials and methods: Manual and electronic database (PubMed, EMBASE and CENTRAL) searches were performed to identify scientific articles, published in English, reporting on mandibular IODs utilizing unsplinted attachments. Studies were included if they were prospective human studies reporting on two-piece microrough surface implants with a diameter ≥3 mm. Data were extracted by two independent investigators, and an overall inter-investigator kappa score was calculated. A meta-analysis was performed on the included comparative studies.

Results: The search shortlisted 30 prospective studies for data extraction and statistical analysis. The included studies comprised of only two randomized controlled trials (RCTs) comparing 1- vs. 2-IODs, and a further 28 prospective studies. The kappa score calculated was between 0.86 and 1 for the various parameters. One RCT favored 1-IODs (RD: 0.08, 95% CI: 0.01, 0.14) while the other favored 2-IODs (RD:−0.04, 95% CI: −0.27, 0.19). However, the overall random effects model did not reveal a significant risk difference (RD) for implant failure between the two interventions (I^2 = 36.6%, P = 0.209; RD: 0.05, 95% CI: −0.07, 0.18).

Conclusions: The results of this meta-analysis conclude that the postloading implant survival of 1-IODs is not significantly different from 2-IODs. However, the existing scientific evidence in the literature in terms of prospective comparative studies is scarce. Hence, before recommending the 1-IOD as a treatment modality, long-term observations are needed and a larger range of functional, prosthodontic, and patient-centered outcome measures should be considered.

Impacts of declining rates of edentulism amongst adult population residing in developed nations have been reported (Mojon et al. 2004; Müller et al. 2007). On one side, this signifies a trend toward minimizing dental diseases; on the other side, it implicates the retention of teeth for a longer period, as tooth loss is still occurring in old age due to neglected hygiene or physical and mental impairment. A direct consequence will be that edentulism will gradually prevail in a much older patient segment, thus presenting the dental profession with more complex cases along with functional impairments related to aging, multimorbidity, and the side effects of its treatment as well as unfavorable anatomical conditions. For these cases, the dental treatment presents a considerable challenge to both, the practitioner and the patient, as neuroplasticity and declining muscular skill may aggravate conventional denture adaptation and diminish neuromuscular control.

The rehabilitation of the edentulous mandible with implant overdentures (IODs) has been reported as an accepted and successful treatment modality, (Raghoebar et al. 2000) which provides a significant improvement of chewing function (van Kampen et al. 2004) and oral health-related quality of life (OHRQoL) (Emami et al. 2009; Rashid et al. 2011), the latter even in very old edentulous patients who are dependent for the activities of daily living (Müller et al. 2013). Mandibular 2-IODs have been proposed as a first choice standard of care in the treatment of edentulous patients (Feine et al. 2002; Thomason et al. 2009). Although, a mandibular overdenture on four implants may be significantly better in terms of support, force distribution, mechanical leverage, and posterior bone protection, reports have

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confirmed that there is no difference in terms of patient satisfaction and function when compared with patients treated with 2-IODs (Wismeijer et al. 1997; Timmerman et al. 2004; Visser et al. 2005; Meijer et al. 2009; Roccuzzo et al. 2012). Hence, a minimum number of implants to support a lower complete denture may be a solution, which is minimally invasive and in addition keeps the treatment cost reasonable. The latter parameters might significantly increase patient acceptance in an elderly edentulous cohort.

Placement of a single implant in the mandibular symphyseal region to retain an overdenture may be an alternative to the 2-implant overdenture, which was proposed as first choice of prosthodontic treatment for the edentulous mandible (Feine et al. 2002), especially in socio-economically challenged edentulous groups. This modality has been reported as a successful treatment concept as early as in the late 90's (Cordioli et al. 1997). More recent reports have confirmed that the 1-IODs do positively improve the OHRQoL in completely edentulous patients as opposed to conventional complete denture therapy (Grover et al. 2014). It was also reported that 1-IODs would be an economical therapeutic advantage in elderly edentulous octogenarians as opposed to conventional complete dentures (Krennmair & Ulm 2001). The 1-IOD therapy might prove beneficial in elderly patients for reasons of physical dependence, mental impairment, diminished manual dexterity, pre-existing medical conditions, and economic factors. However, this treatment concept needs to be thoroughly investigated with well-designed clinical trials comprising of a wide range of functional, prosthodontic, and patient-centered outcome measures before being recommended as a reliable protocol.

Hence, this systematic review was performed to test our hypothesis that 1-IODs show similar outcomes in terms of postloading implant survival when compared to 2-IODs. Therefore, for the purpose of this review, the formulated PICO (population, intervention/exposure, comparison, outcome) question was "Do 1-IODs have similar outcomes in terms of implant survival when compared to 2-IODs in the edentulous mandible?"

Material and methods

This systematic review protocol was conducted and reported in strict accordance with the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines (Moher et al. 2010).

Eligibility criteria

Studies were included in the review if they fulfilled the predefined set inclusion criteria (Table 1).

Information sources

Electronic databases (PubMed, Embase and CENTRAL) were searched to identify prospective human studies published in English, between January 1980 and January 2014, reporting on mandibular IODs with unsplinted attachments. Hand searches were performed for articles not available in electronic database records. The last-performed search was on the 8th of January 2014; no further search was performed after this date.

Search strategy

An expert on database searches (FM) and the investigators (MS and NAM) set up the search design. Two investigators (MS and NAM) independently performed the database searches. The complete search strategy, terms, along with the search builder combination is presented in Table 1. References were verified from the shortlisted articles and cross-checked from other published systematic reviews to avoid exclusion of relevant studies.

Study selection

The available research on the relevant topic was scarce, and hence, no restrictions were applied to the type of studies included, which comprised of randomized controlled trials (RCTs), prospective cohort studies, case–control studies, and prospective case series.

Data collection process and data items

Two investigators (MS and NAM) independently shortlisted the searched articles by initially performing a thorough title and abstract screening. Inclusion of articles for the full text analysis was performed only after a mutual agreement between the two. In cases of disagreements, it was resolved by means of a consensus discussion presided over by the senior author (FM). Data extraction was performed after a mutual agreement on the final list of included publications. Data were extracted independently by the two investigators (MS and NAM) and were reciprocally blinded to each other's extraction.

The following information was extracted: name of author(s), publication year, study design, intervention type, loading protocol, implant system, attachment type, observation period, number of patients, number of implants placed and failed, dropouts, and the reported implant survival rate percentage (SR%).

Missing data

If the included articles had any missing relevant information articles, corresponding authors were contacted by email. In case of nonresponses, reminder emails were sent.

Risk of bias in studies and quality assessment

The included RCTs were assessed for risk of study bias using the Cochrane collaboration's tool (Higgins et al. 2011). Newcastle–Ottawa scales (NOS) were to be used to assess the methodological quality of the included prospective cohort studies and case–control studies (Wells et al. 2014). In cases of multiple publications from authors reporting on the same cohort, only the most recent report was included.

Outcome measures

The primary outcome measure analyzed in this review was postloading implant survival rates as performed in former published reviews (Schimmel et al. 2014; Srinivasan et al. 2014). Implant success or survival was defined as the absence of mobility, pain, recurrent peri-implant infection, and continued radiolucency around the implant (Buser et al. 1990). For the purpose of this review, the definitions of loading protocols adopted are as defined in previous systematic reviews (Esposito et al. 2007; Schimmel et al. 2014). Information on overdenture survival and maintenance was not consistently reported and is therefore not reported in this paper.

Statistical analysis

The interinvestigator reliability was expressed as a percentage of agreement adjusted for chance using Cohen's unweighted kappa (κ). The meta-analysis was performed for the identified RCTs using the STATA command "metan" (Harris et al. 2008). Confidence intervals were set at 95% (95% CI); risk differences (RD) for the implant survival rates were calculated and compared between the two studied interventions (1-IODs and 2-IODs). Weighted means across the studies were calculated using a random effects model. Heterogeneity between the studies was assessed using the *I*-squared statistic (I^2-statistic), which describes the variation percentage due to heterogeneity rather than chance (Harris et al. 2008).

Table 1. **Eligibility criteria, information sources and systematic search strategy**

Focus question	Do 1-implant overdentures (IODs) have similar outcomes in terms of implant survival when compared to 2-IODs in the edentulous mandible?	
Eligibility criteria	Inclusion criteria	• Prospective studies reporting on dental implants placed in the edentulous human mandible • Implant overdentures retained by 1 or 2 implants using unsplinted attachments. • Studies must specify the study design, number of patients, number of implants placed and failed, time of loading, and number of dropouts • Implant type: two-piece, micro-rough surface solid screw type implants • Patients must have been clinically examined during recall.
	Exclusion criteria	• Studies with postloading observation periods of <12 months • Implants placed in irradiated or augmented bone • Reports with sample size of <10 cases, • Implant diameter <3 mm
Information sources	Electronic databases	PubMed, Embase and the Cochrane Central Register of Controlled Trials (CENTRAL)
	Journals	All peer reviewed dental journals available in PubMed, Embase and CENTRAL. No filters were applied for the journals.
	Others	Reference crosschecks, personal contacts with authors, etc.
Search terms	Population	# 1 – ((Dental prosthesis, Implant supported [MeSH] OR (Overdentures [MeSH]) OR (Jaw, Edentulous [MeSH]) OR (Mandible [MeSH]) OR (Mouth, Edentulous [MeSH]) OR (Removable dental prostheses* [all fields]) OR (Overdentures [all fields]) OR (Implant supported overdentures [all fields]) OR (Implant assisted Overdentures [all fields])) AND
	Intervention or exposure	#2 – ((Dental implantation, endosseous [MeSH]) OR (dental implants [MeSH]) OR (Dental prosthesis, Implant supported [MeSH]) OR (Dental implantation [all fields] OR (Dental implant [all fields] OR (Dental implants [all fields])) AND
	Comparison	#3 – ((Single implant overdentures [all fields]) OR (Two implant overdentures [all fields]) OR (Two implant supported overdentures [all fields]) OR (Two implant retained overdentures [all fields])) AND
	Outcome	#4 – ((Dental restoration failure [MeSH]) OR (Implant survival [all fields]) OR (Dental prosthesis failure [all fields])) AND
Filters	Language	# 5 – (English [lang])
Search builder	Combination	#1 AND #2 AND #3 AND #4 AND #5

All statistical tests were performed using the STATA statistical software release version 13.1 (StataCorp LP, College Station, TX, USA) by a specialist biostatistician (FRH).

Additional descriptive analysis was performed on the included noncomparative prospective studies.

Results

Study identification and selection

The detailed data search, identification, and selection process are reported as per the PRISMA guidelines (Moher et al. 2010) and are presented in a flow diagram (Fig. 1). The electronic search yielded a total of 12,443 articles (PubMed = 8031; Embase = 1490; CENTRAL = 2922) and retrieved a further 5 relevant articles from the reference crosschecks. Fifty-four prospective studies were included for full text analysis. From these, two relevant prospective studies on 1-IODs were excluded. One was excluded because it was retracted after publication, (El-Sheikh et al. 2012a) while the other (Grover et al. 2014) had missing relevant information pertaining to this review.

Finally, 30 methodologically sound publications were included for data extraction and statistical analysis, which included only two RCTs comparing 1- vs. 2-IODs (Table 2) and 28 prospective reports (Tables 3 and 4). Publication bias was cautiously avoided, and many studies were excluded because the authors reported on the same cohort at different time points. The included RCTs had different lengths of observation periods (Bryant et al.

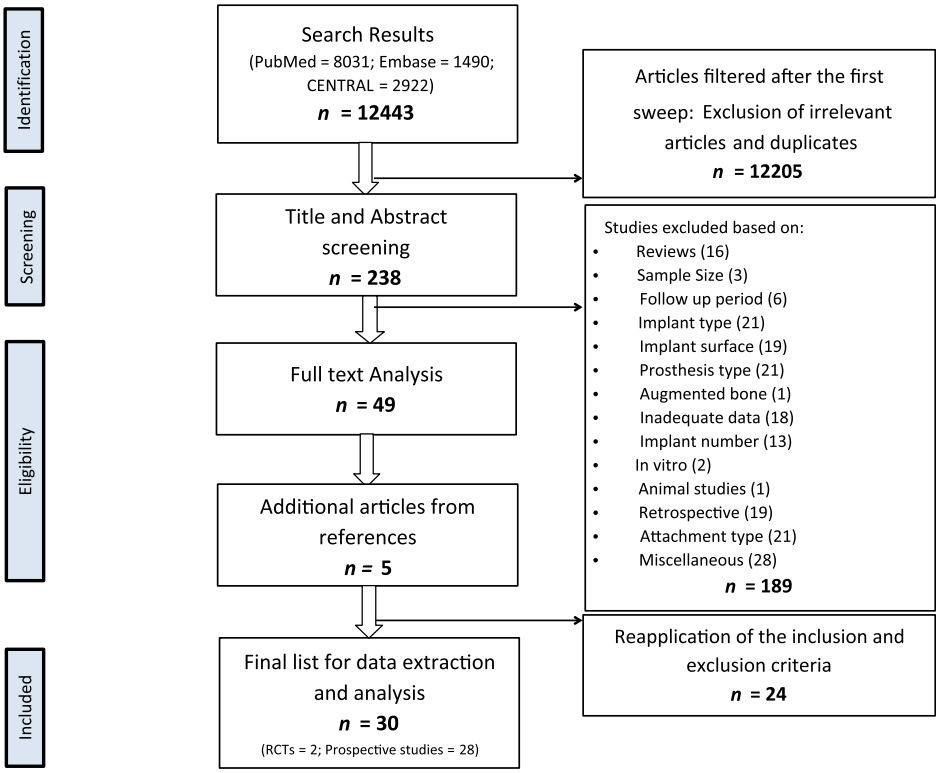

Fig. 1. Flow diagram showing the details of the data search, identification, and selection process in accordance with the PRISMA (preferred reporting items for systematic reviews and meta-analysis) guidelines. *n*-number.

Table 2. **RCTs comparing 1- vs. 2- implant overdentures in the completely edentulous mandible**

Study (first author)	Year	study design	Treatment groups compared	Loading time (in days)	Jaw	Implant system	Attachment type	Observation period (months)	Subjects included	Implants per subject	Implants placed	Subjects analyzed*	Implants survived* (Failed)	Reported SR (%)†
Kronstrom	2014	RCT	1-IOD	Immediate (0)	Mandible	Nobel	Ball	36	17	1	17	11	11 (3)	81.8‡
			2-IOD	Immediate (0)	Mandible	Nobel	Ball	36	19	2	38	8	16 (7)	
Bryant§	2014	RCT	1-IOD	Early (42)	Mandible	Straumann	Ball	60	42	1	42	29	29 (0)	100
			2-IOD	Early (42)	Mandible	Straumann	Ball	60	44	2	92¶	33	66 (5)	94.3

RCT, randomized controlled trial; SR, survival rate; NR, not reported;
*Includes dropouts.
†SR at end of observation, but all failures occur within the first year.
‡Overall survival rate.
§Data supplied by authors. (accepted for publication).
¶Failed implants were replaced.

Table 3. **Prospective studies and RCTs reporting on mandibular 1- implant overdentures**

Study (first author)	Year	Loading protocol	Loading time (in days)	Implant system	Attachment type	Observation period (in months)	Subjects	Implants per subject	Implants placed	Total survived* (Failed)	Reported SR (%)
Alsabeeha	2011	Early	42	Southern, NeOss	Ball, LOCATOR	12	36	1	36	34 (1)	91.7
Harder	2011	Conventional	Not specified	Camlog	Ball	35–52	11	1	11	10 (0)	100†
Liddleow	2010	Immediate	0	Nobel	Ball	36	25	1	25	25 (0)	100
Total	2010–2011		0–42+		Unsplinted	12–52	72	1	72	69 (1)	91.7–100

SR, survival rate; NR, not reported; RCT, randomized controlled trial.
*Includes dropouts.
†Information confirmed directly from the authors.

2014, Kronstrom et al. 2014): one reported 3-year results (Kronstrom et al. 2014), while the other was a 5-year report recently accepted for publication, (Bryant et al. 2014).

Risk of bias/Quality assessment

The Cochrane collaboration's tool for assessment of the risk of publication bias was used for the included RCTs (Table 5). Both studies were graded with a low risk of bias. As the remaining prospective studies included in this review were not purposefully designed to compare the two investigated protocols, they were classified as prospective case series and were not to be assessed for quality by the NOS.

Inter-investigator agreement

The inter-investigator agreement was calculated for the various parameters extracted and was considered good ($\kappa = 0.86–1$).

Meta-analysis of RCTs

The meta-analysis of the two RCTs comparing the 1-IODs and 2-IODs failed to demonstrate any significant RDs for the postloading implant survival between the two modalities. The forest plot (Fig. 2) revealed that one study (Kronstrom et al. 2010) slightly favored 2-IODs (RD: −0.04, 95% CI: −0.27, 0.19); while the other (Bryant et al. 2014) demonstrated a slight tendency toward 1-IODs (RD: 0.08, 95% CI: 0.01, 0.14). However, the overall RDs for implant survival for the two interventions were not significant ($I^2 = 36.6\%$, $P = 0.209$; RD: 0.05, 95% CI: −0.07, 0.18). As the length of follow-up in both studies was different with a large number of dropouts, a sensitivity analysis was performed considering the dropouts as failures. The forest plot (Fig. 3) revealed an inversion of the earlier tendencies. However, the overall RDs for implant survival in the sensitivity analysis still remained insignificant between the two studies ($I^2 = 57.7\%$, $P = 0.124$; RD: 0.07, 95% CI: −0.17, 0.32). The risk of bias across the studies was considered low for both the RCTs.

Descriptive analysis of prospective studies and RCTs not comparing the tested interventions

Additional descriptive analysis was performed on the remaining included prospective studies and RCTs.

Mandibular 1-IODs

Two prospective studies and one RCT (Liddelow & Henry 2010; Alsabeeha et al. 2011; Harder et al. 2011) reporting on 1-IODs with ball or LOCATOR® attachments reported sur-

Table 4. **Prospective studies and RCTs reporting on mandibular 2- implant overdentures**

Study (first author)	Year	Loading protocol	Loading time (in days)	Implant system	Attachment type	Observation period (in months)	Subjects	Implants per subject	Implants placed	Total survived* (Failed)	Reported SR (%)
Akoglu	2011	Conventional	56	Straumann, Astra, Zimmer	Ball	60	36	2	72	72 (0)	100
Cakarer	2011	Conventional	60	Straumann, Nobel, Frialit, Swiss-Plus, Biohorizons, Bio-Lok	Ball	12–60	19	2	38	38 (0)	NR
Cooper	2008	Conventional	90	Astra	Ball	60	59	2	118	98 (5)	95.9
Cune	2004	Conventional	117	Frialoc	Ball	12	18	2	36	34 (2)	93.9
De Kok	2011	Conventional	56	Astra	Ball	12	10	2	20	20 (0)	100
El-Sheikh	2012	Conventional	70	Straumann	LOCATOR	24	10	2	20	20 (0)	100
ElSyad	2012	Conventional	90	ImplantDirect	Ball	36	18	2	36	30 (0)	NR
Gotfredsen	2000	Conventional	90	Astra	Ball	12–60	15	2	30	28 (1)	NR
Hobkirk	2008	Conventional	90	Southern	Ball	12	30	2	60	38 (2)	NR
Kleis	2010	Conventional	105	3i-Biomet	Ball/LOCATOR	12	60	2	120	112 (8)	90.4
Klemetti	2003	Conventional	70	Straumann	Ball	12	30	2	60	59 (1)	NR
Krennmair	2011	Conventional	90	Camlog	Ball/Telescope	12–60	25	2	50	38 (0)	100
Ma	2010	Conventional	84	Straumann, Southern	Ball	12–120	24	2	48	17 (0)	100
Røynesdal	2001	Conventional	90	Straumann	Ball	24	10	2	20	18 (0)	100
Turkyilmaz	2012	Conventional	90	Nobel	Ball	12–84	13	2	26	24 (0)	100
Total (15)	2000–2012	Conventional	56–117		Unsplinted	12–120	377	2	754	646 (19)	90.4–100
Al-Nawas	2012	Early	42	Straumann	LOCATOR	12	91	2	182	173 (5)	98.9/97.9
Cehreli	2010	Early	42	Straumann, Brånemark	Ball	60	28	2	56	44 (0)	NR
Cristache	2012	Early	42	Straumann	Ball/ LOCATOR/ Magnets	60	69	2	138	134 (4)	97.1
Gadallah	2012	Early	7/42	Zimmer	Ball	12	12	2	24	24 (0)	100
Ma	2010	Early	14	Straumann, Southern	Ball	12–120	48	2	96	66 (0)	100
Røynesdal	2001	Early	21	Straumann	Ball	24	11	2	22	20 (0)	100
Turkyilmaz	2012	Early	7	Nobel	Ball	12–84	13	2	26	24 (0)	100
Total	2001–2012	Early	7–42		Unsplinted	12–120	272	2	544	485 (9)	97.1–100
Büttel	2012	Immediate	0	Straumann	Ball	24–36	20	2	40	38 (0)	100
Elsyad	2012	Immediate	0	ImplantDirect	Ball	36	18	2	36	30 (2)	NR
Engelke	2011	Immediate	0	Semados	Ball	36	20	2	40	40 (0)	100
Grandi	2012	Immediate	0	JD Evolution	Ball	12	42	2	84	84 (0)	100
Liao	2010	Immediate	0	Nobel	Ball	12	10	2	20	16 (4)	94
Marzola	2007	Immediate	0	Nobel	Ball	12	17	2	34	34 (0)	100
Ormianer	2006	Immediate	0	Zimmer	Ball	12–30	10	2	20	19 (1)	96.4
Total	2006–2012	Immediate	0		Unsplinted	12–36	137	2	274	261 (7)	94–100
Overall Total	2000–2012	All protocols	0–117		Unsplinted	12–120	786	2	1572	1392 (35)	90.4–100

SR, survival rate; NR, not reported; RCT, randomized controlled trial.
*Includes dropouts.

Table 5. **Quality assessment of the included randomized controlled trials**

	Risk of bias assessed according to the various domains in the Cochrane collaboration's tool					
Study (first Author and year)	Sequence generation	Allocation concealment	Blinding	Incomplete outcome data	Selective outcome reporting	Other sources of bias
Kronstrom 2014	Low	Unclear	Unclear	Low	Low	Low
Bryant 2014	Low	Low	Low	Low	Low	Low

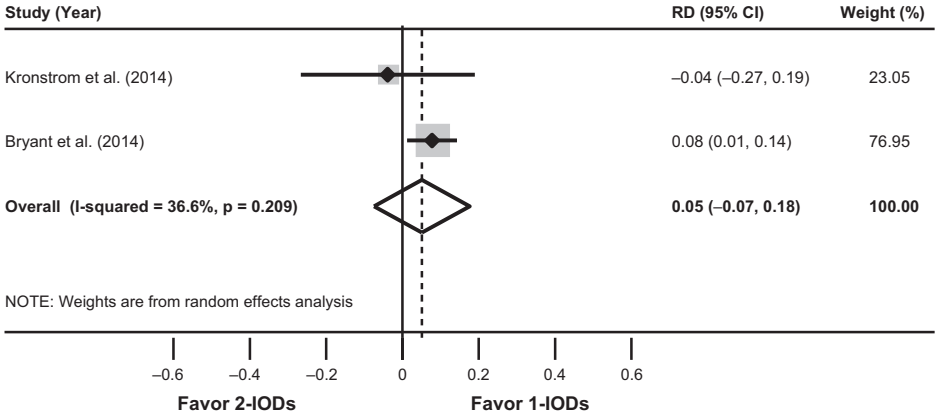

Fig. 2. Forest plot showing the comparison of implant survival outcomes with 1- vs. 2- IODs. CI-confidence interval; RD-risk differences; IODs-implant overdentures.

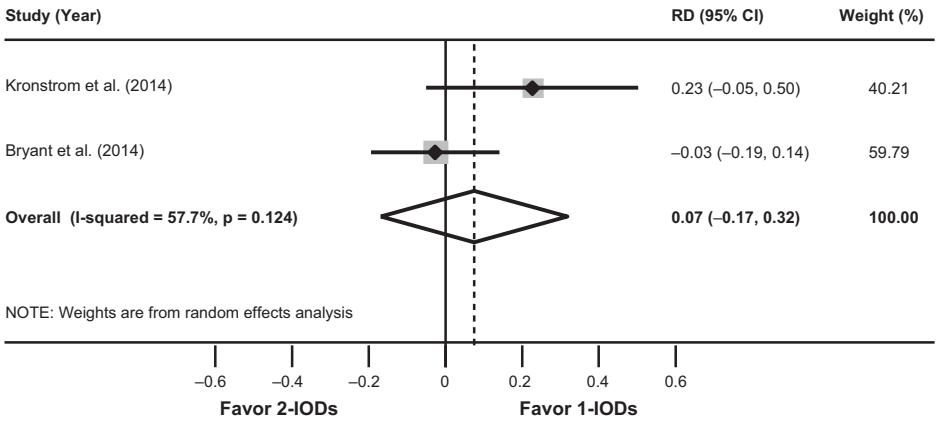

Fig. 3. Forest plot showing the sensitivity analysis when considering dropouts also as failures. CI-confidence interval; RD-risk differences; IODs-implant overdentures.

vival rates of 91.7–100% over a postloading observation period of 12–52 months (Table 3). These three studies assessed a total of 72 implants placed in 72 patients with only one reported implant failure. A single implant failure was reported in the study where an early loading protocol was employed (Alsabeeha et al. 2011). The other study employed an immediate loading protocol, reported no implant failures in 25 patients, and an implant survival rate of 100% over a 36-month observation period (Liddelow & Henry 2010). The only study employing a conventional loading protocol, in this 1-IODs group, although having no reported implant failures did not declare a survival rate in the publication (Harder et al. 2011). However, after directly contacting the authors, they confirmed a 100% survival rate with only one patient dropout (who died at the 35th month of the 3-year observation period). The authors' 5-year follow-up report declared no further implant losses for the same cohort and was published as an IADR abstract in 2013 (Passia et al. 2013).

Mandibular 2-IODs

Twenty-five studies, which comprised of prospective studies and RCTs, reported on 2-IODs (Gotfredsen & Holm 2000; Roynesdal et al. 2001; Klemetti et al. 2003; Cune et al. 2004; Ormianer et al. 2006; Marzola et al. 2007; Cooper et al. 2008; Hobkirk et al. 2008; Cehreli et al. 2010; Kleis et al. 2010; Liao et al. 2010; Ma et al. 2010; Akoglu et al. 2011; Cakarer et al. 2011; De Kok et al. 2011; Engelke et al. 2011; Krennmair et al. 2011; Al-Nawas et al. 2012; Büttel et al. 2012; El-Sheikh et al. 2012b; Elsyad et al. 2012; Gadallah et al. 2012; Grandi et al. 2012; Turkyilmaz et al. 2012; Cristache et al. 2014). A total of 1572 implants were placed in 786 patients and of these only 35 implants were reported as failures, thus demonstrating a cumulative survival rate between 90.4% and 100% (Table 4).

Seven studies employed an immediate loading protocol with reported survival rates ranging between 94% and 100% (patients = 137; implants placed = 274; implants failed = 7). Four of these seven studies reported 100% survival rates over an observation period of 12–36 months (Marzola et al. 2007; Engelke et al. 2011; Büttel et al. 2012; Grandi et al. 2012).

Seven studies reporting on 2-IODs with an early loading protocol reported a survival rate ranging from 97.1% to 100% over an observation period of 12–120 months (patients = 272; implants placed = 544; implants failed = 9). Four of these studies reported a survival rate of 100% over an observation period of 12 months up to 10 years (Roynesdal et al. 2001; Ma et al. 2010; Gadallah et al. 2012; Turkyilmaz et al. 2012).

The remaining studies in this 2-IODs group employed a conventional loading protocol and over an observation period of 12–120 months reported a survival rate between 90.4% and 100% (patients = 377; implants placed = 754; implants failed = 19). Seven studies (Roynesdal et al. 2001; Ma et al. 2010; Akoglu et al. 2011; De Kok et al. 2011; Krennmair et al. 2011; El-Sheikh et al. 2012b; Turkyilmaz et al. 2012) with a conventional loading protocol in the 2-IODs

group reported a 100% survival over an observation period of 12–120 months.

Discussion

The findings of this meta-analysis of studies with higher evidence (RCTs), included in this review, revealed no significant difference between the RD of the two investigated interventions (1-IODs vs. 2-IODs) with respect to implant survival. On a further careful analysis of the forest plot (Fig. 2), it is easily discernible that one of the two included RCTs slightly favored 1-IODs (Bryant et al. 2014), whereas the other study was partial toward the 2-IODs (Kronstrom et al. 2014). The overall analysis of the RD was not significant ($P = 0.209$). In terms of strength of the evidence analyzed, the two included RCTs were of sound methodological quality by well-known researchers and assessed with a low risk for study bias. Additional descriptive analysis of the studies with the lesser evidence reveals slightly better survival rates (91.7–100%) for the 1-IODs as opposed to the 2-IODs (90.4–100%). However, this slight difference could not be statistically verified because of the descriptive nature of these findings. Most of these studies in this group were either prospective cohorts or RCTs not comparing our investigated interventions. Therefore, these studies were classified as prospective case series in our review and categorized as studies with lower evidences. Retrospective reports were excluded to avoid commonly encountered study biases such as inclusion bias, underestimating implant failures, or other adverse events, as pointed out in a previous systematic review (Schimmel et al. 2014).

Although the methodology applied and the strict adherence to the PRISMA guidelines in conducting this review may be considered robust, the conclusions drawn from this review should be interpreted with caution. This review delivers a meta-analysis of the RCTs, and even though meta-analysis of RCTs are considered as the highest level of confirmatory scientific evidence today (Glenny et al. 2008), it must be retained that the review included only two RCTs in the analysis. This is relatively a small number to draw a meaningful conclusion. However, as the studies included had relatively decent observation periods, that is 3 and 5 years, the conclusions drawn from them add weight. However, the minimum observation period of included studies remained 12 months, as we consider this observation period relevant for a first evaluation of a new treatment concept as performed in former reviews (Schimmel et al. 2014; Srinivasan et al. 2014). Another key factor to consider is that both the studies did not follow the same loading protocol. One employed an immediate loading protocol (Kronstrom et al. 2014), while the other employed an early loading protocol (Bryant et al. 2014). The effects of loading protocols could have overshadowed the treatment effect. However, this cannot be confirmed unless studies with similar loading protocols were used to compare the two studied interventions. This could be an important factor as most implant failures are found to occur initially, that is before loading. It is important to point out that the observation periods of the two RCTs were not the same (3 and 5 years), but the comparison could still be made because the implant failures in both the studies only occurred in the first year and the none after that. Hence, a comparison was possible.

Our stringent inclusion criteria and purposeful exclusion of retrospective reports may have greatly reduced the number of included studies. However, this was necessary to ensure that only the methodologically sound studies with low study bias were included in this meta-analysis.

This review cannot reject the null hypothesis that the outcomes of both the investigated interventions are similar. This is as was confirmed in previous reports employing the 1-IODs protocol (Cordioli et al. 1997; Liddelow & Henry 2010; Alsabeeha et al. 2011; Harder et al. 2011). The scope for the application of this protocol may be overwhelming. This treatment modality has the potential to eventually become the new minimum standard recommended for the compromised elderly edentulous patients, as the original McGill consensus may with time come under threat with the accumulation of more robust evidence for the mandibular 1-IODs particularly with long-term outcomes beyond 10 years. For reasons stated earlier, the treatment of the compromised elders requires a minimally invasive yet an effective approach. The 1-IODs may just provide such a solution in elderly edentulous patients. On a different note, this protocol may yet have an economical advantage for the healthcare policy makers. Walton et al. (2009) reported that the initial treatment and the subsequent maintenance costs associated with the 1-IOD therapy were considerably less than that of the 2-IODs in their study (Walton et al. 2009). Therefore, this protocol would reduce the healthcare costs as compared to the conventional implant 2-IODs, where in, a significantly larger number would be able to receive IODs; in other words, more people would be benefitted with an advanced therapy for the same projected healthcare cost estimates.

From a clinical point of view, the placement of implants in the midline should be approached with a considerable amount of caution, as it has been reported that there is a risk of injury to the midline lingual canal vessels, especially in women (Oettle et al. 2013). Another aspect for critical appraisal would be that in 1-midline, IODs present an additional degree of freedom as denture kinetics is not limited to a rotation of the denture during occlusal load, clinically evident as sinking in of the posterior denture saddles. One IODs may be associated with excessive lateral movements especially when the occlusion presents with premature contacts. As occlusion in complete dentures is dynamic and changes during the wearing period, regular remounting of the dentures is recommended. It has to be borne in mind that even if a perfect occlusion is present at delivery, changes in occlusion may occur unnoticed, thus resulting in occlusal interferences up to several millimeters (Utz 1997). The forces resulting from lateral denture displacement during occlusion may accelerate the lateral bone resorption of the posterior alveolar ridges that may be a significant functional disadvantage in comparison with the 2-IODs, albeit evidence is still lacking for this hypothesis. The additional degree of freedom may also influence denture stability and consequently the chewing efficiency. This parameter has also not yet been investigated, despite it being one of the main motivators for elderly persons to accept implant treatment.

Another factor to consider is the posterior bone loss. A large area of support, as present in a 4-implant overdenture, seems to prevent posterior bone loss in comparison with a 2-implant overdenture (de Jong et al. 2010). However, elderly patients tend to exert less muscle force due to age-related atrophy (Newton et al. 1993), and thus, there is little mechanical load to accelerate the posterior bone atrophy. Of course, the alveolar resorption is multifactorial and not yet fully understood; mechanical load may be just one factor to be considered.

Finally, the issue of patient satisfaction must be addressed. Although significant improvements of the OHRQoL have been reported in literature, this however may not be a lasting effect. Walton et al. (2009)

highlighted the "rebound" effect in nine patients who were initially dissatisfied with their prostheses before entering their study (Walton et al. 2009). Eight of these patients overwhelmingly improved their satisfaction scores at 2-month postimplant retention. The same eight patients later indicated decreased satisfaction scores at the 1-year follow-up visit, albeit still higher than their baseline scores for six of the eight patients. These findings emphasize that patient satisfaction should be evaluated over a long-term; otherwise, they could be misleading. However, whatever number of implants used to retain an overdenture, realistically, 100% patient satisfaction can never be achieved because a nonbiological prosthesis fails to fully restore the lost tissue and oral function.

Conclusions

The results of this systematic review and meta-analysis conclude that 1-IODs have no significantly different outcomes, with respect to postloading implant survival, as that of 2-IODs. However, before recommending the 1-IOD as a definitive treatment modality, long-term observations are needed and a larger range of functional, prosthodontic, cost-effective, and patient-centered outcome measures should be considered.

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