REVIEW ARTICLE

Survival Rate of Surface-treated Mini-implants: A Systematic Review

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Abstract

Background: Various surface treatments have been carried out to improve the stability of the orthodontic mini-implants (OMIs) and reduce the failure rate. The current review aimed to systematically analyze and report on the evidence about the survival rates of OMIs that are subjected to surface treatment.

Objective: To report on survival rates of OMIs subjected to surface treatment.

Materials and methods: Search—a complete search on the survival rate of surface-treated OMIs across the following electronic databases PubMed, Cochrane, Google Scholar, and a manual search of orthodontic journals was performed till December 2022. Studies were selected on the basis of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Results: Four randomized controlled trials (RCT) and three prospective clinical trials (PCTs) were included in this review. A total of 379 mini-implants were assessed, out of which 193 OMIs were surface treated. Of the seven studies assessed, four RCTs had a moderate/unclear risk of bias (ROB). Out of three prospective studies, two were of poor quality, and one was moderate. All studies reported higher survival rates of surface-treated OMIs than the nontreated OMIs. No significant differences between surface-treated and nontreated OMIs were noted for insertion torques and mobility.

Conclusion: Surface treatment of OMIs significantly improved the survival rate. Insertion torques and mobility were not affected by the surface treatment of OMIs. These results should be interpreted with caution as the overall ROB in the studies included was moderate to high.

Keywords: Acid-etched mini-implant, OMIs, Sandblasted mini-implant, Surface-treated mini-implant, Temporary anchorage device.

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Introduction

The advent of orthodontic mini-implants (OMIs) brought about a shift in the paradigm of orthodontic anchorage. Tooth movements that were once difficult to achieve have become easier because of OMIs. By virtue of expanding the envelope of a discrepancy, OMIs facilitate the treatment of borderline cases nonsurgically.

Skeletal anchorage has evolved due to OMIs because of their simplicity of placement and removal, as well as their low cost.[1] These devices provide absolute anchorage without patient cooperation and also tolerate reaction forces and have hence become a necessary part of an orthodontist's skill set and armamentarium.[2,3] The clinical success rate and risk factors for failure of OMIs are of paramount importance in application to orthodontic treatment. Reportedly, there is a 10–15% OMIs failure rate, while their success rate varies between 61 and 90%.[4]

Factors responsible for the success rates of OMIs vary from patient-dependent factors, for example, age, anatomical location of OMI placement, bone quality, and interradicular space, implant-related factors like screw diameter and length, screw design, surface topography, and as well as operator skill.[5,6] Previous studies have reported that patients with high mandibular plane angle have a higher OMI failure rate than those with normal and low mandibular plane angle.[7] It has also been reported that there is a great risk of failure of OMIs in adolescent patients due to active bone metabolism and low bone maturation[8]; these factors play a role in the stability of temporary anchorage devices.

Various surface treatments have been carried out to increase the stability of OMIs and reduce the failure rate. Increasing surface roughness causes a change in surface topography mimicking natural bone, which in turn causes increased interdigitation between OMI and bone.[9] A change in surface topography also affects cell growth and orientation.[10]

There are no reported systematic reviews of clinical trials on surface-treated OMIs. Animal studies have reported on the stability and success rate of surface-treated OMIs. Al-Thomali et al., in their review on surface-treated OMIs with animal studies, concluded that surface-treated OMIs showed improved primary stability and good osseointegration at the bone-implant surface, facilitating better secondary stability. Therefore, the aim of the present systematic review was to systematically analyze the available human prospective studies on survival rates of OMIs subjected to surface treatment.

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Materials and Methods

Review Question

This review was performed in adherence to the PRISMA guidelines. The review protocol was registered with PROSPERO-CRD42021241196. The review question of the present study was the following—does the surface treatment of OMIs improve the survival rate and primary stability, and does it affect the other parameters?

Population, Intervention, Comparison, and Outcomes (PICO) and eligibility criteria:

- P—human *in vivo* studies.
- I—OMIs that are surface treated.
- C—OMIs, nonsurface treated.
- O—survival rate, insertion and removal torque, mobility, pain, and inflammation

Eligibility

Studies in the English language that assessed the influence of surface treatment/modification on the survival rate of OMIs were included. *In vitro* studies, editorial letters, case reports, case series, studies that did not explore the impact of surface treatment on the mechanical stability of OMIs, and OMIs without surface modification/treatment were all automatically disqualified from consideration at this stage (Table 1).

Search Strategy

PubMed, Cochrane Library (Cochrane Review, Trails), and Google Scholar databases were searched. Not to omit gray literature, the following databases were searched—Google Scholar, Open Grey, and Social Science Research. The search was conducted, including articles dated from January 2000 to December 2022. Also, reference lists of all articles included were searched for any missed out studies. The keywords used and the databases searched are mentioned in Table 2.

Study Selection

For inclusion in the study, each title and abstract were reviewed independently and also checked for duplicates. Using an intraclass correlation coefficient, the interrater agreement for study inclusion was 0.95. Consensus discussions between the two reviewers were used to settle conflicts.

Risk of Bias (ROB) Assessment

The ROB was assessed using Cochrane's ROB tool (Cochrane ROB-1).[5] The sorted-out studies were assessed with the following domains—random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases. Each domain was categorized as low risk, high risk, or unclear risk depending on yes, no, or unclear judgment, respectively. The risk assessment of the nonrandomized prospective trials was done using the Newcastle-Ottawa scale.[5,6]

Table 1: Population, intervention, comparison, and outcomes (PICO)-based eligibility criteria

Category	*Inclusion criteria*	*Exclusion criteria*
Participants	RCTs, prospective, or retrospective controlled human clinical trials reporting on the placement of OMIs.	Animal studies, systematic reviews, reviews, *in vitro* studies, and case reports.
Intervention	Surface-treated interradicular OMIs (acid-etching or sandblasting).	Mini plates, IZC screws, and buccal shelf screws.
Control	Nontreated inter-radicular OMIs.	
Outcome	The survival rate of the mini-implants.	

OMIs, orthodontic mini-implants

Data Extraction and Synthesis

The data extraction was done independently by two reviewers with an Excel sheet, and any disagreements were resolved by discussion. The following data were extracted from each included study—first author, year of publication, study design, sample size, inclusion and exclusion criteria, study quality, type of surface treatment, OMIs used, method of analysis, loading information, insertion and removal torque values, mobility, statistical analysis used, and the authors' conclusion.

Results

The data available from the year 2000 to 2022 were collected. Applying the search strategy, 385 articles were identified. Of the 385 records identified after a thorough search, Duplication was assessed using R software and 129 articles were excluded, and 256 records were retrieved. Then 242 records were then excluded after reading the titles and abstracts, which were found to be irrelevant. From the nine articles selected for full-text reading, two articles were excluded as they failed to include a control group and did not assess the survival rate of OMIs (Table 3). Finally, seven articles were included in the qualitative analysis, all of which were human studies. Meta-analysis was not carried out due to heterogeneity in methods of assessment of implant stability." Thus, seven studies were ultimately subjected to qualitative analysis. The overall method of extraction of the studies was represented with a PRISMA flow diagram in Flowchart 1.

Study Characteristics

Of the seven studies included for final analysis, all four RCTs were assessed to be of moderate risk. None of the four studies reported blinding of the clinician, and no data on the method of outcome assessment was mentioned.[7–10] Thus, the overall quality of the RCTs was concluded to be moderate/unclear (Table 4). Assessment of bias for the prospective nonrandomized trials showed that one of the studies had fair quality[11] and the other two were of poor quality (Table 5).[12–14] A total of 379 OMIs were assessed in the included studies; six of the seven included studies employed sandblasting, acid etching methods of surface treatment, and one study used anodization for surface modification. Implant loading was done in all the studies; immediate loading in two studies[11,14] loading after 6 weeks in one study,[7] after 4 weeks in three studies[8,10,12,13] after 2 weeks in one of the studies.[8] The gender distribution reported in the included articles was not even, and there were more females. The overall characteristics of the studies included are described in Table 6.

Study Outcomes

The survival rate or success rate of OMIs was reported in all the studies included. The overall success rate ranged from 81.5 to 100% and 66–100% for the surface-treated and nontreated OMIs. Hence in all the studies, a high survival rate for surface-treated OMIs was reported.

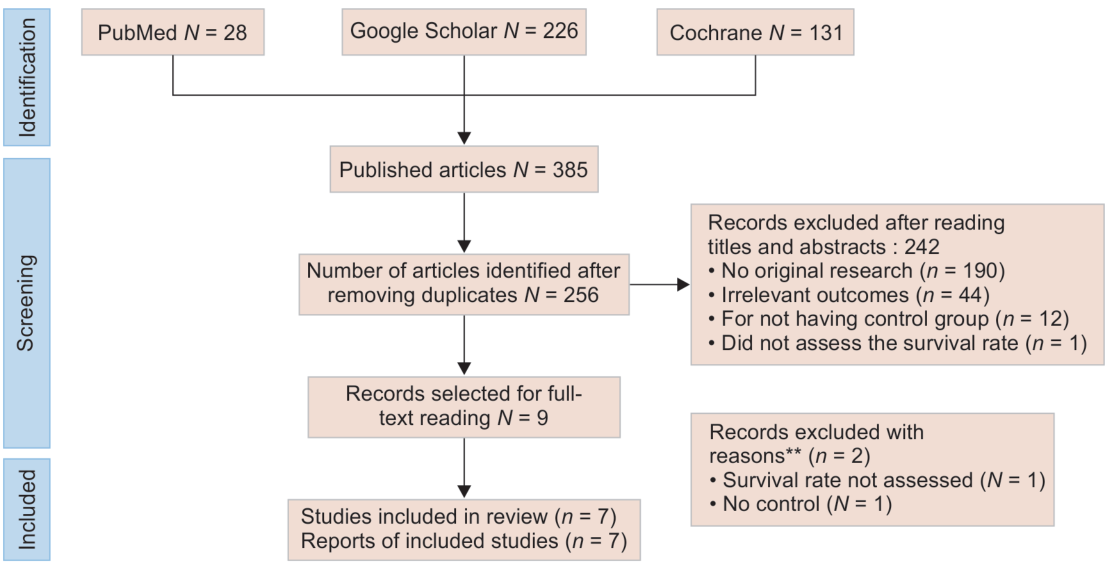
Table 2: Keywords used and the databases searched

Database searched	*Keywords*	*Results*
PubMed	(mini implants) OR (ORMs) OR (mini screws) OR (orthodontic mini-screws) OR (temporary anchorage devices) OR (skeletal anchorage)) OR (micro implants)) OR (microimplants) OR (titanium miniscrew) OR (orthodontic anchorage) OR (temporary skeletal anchorage) AND (orthodontic patients)) AND (orthodontic movement) AND (surface treated mini implants)) OR (surface treated mini screw) OR (surface treated titanium screw) OR (surface-treated titanium mini-implant)) OR (surface treated stainless steel mini implant)) OR (anodic oxidization) OR (anodic oxidization) OR (plasma ion implantation) OR (ion implantation) OR (sandblasting) AND (untreated mini implants) OR (untreated mini-implants) OR (untreated mini-screws) OR (untreated mini-screws) OR (mini-implant stability) OR (survival rate of mini-implant) OR (mini-implant failure) OR (mini-implant mobility) OR (primary stability of mini-implant) OR (secondary stability of mini-implant) OR (success rate of mini-implant) OR (failure rate mini-implant).	28
Google Scholar	Surface treated OMIs OR surface modified OMIs AND sandblasted orthodontic mini-implant OR etched mini-implant OR acid etched orthodontic mini-implant OR surface etched orthodontic mini-implant AND stability of OMIs.	226
Cochrane	(OMIs) OR (mini-screw) AND (surface treated) OR (acid-etched) AND (survival rate).	131

Table 3: Records excluded with reasons

No.	*Author*	*Year*	*Reasons for exclusion*
1	Lee et al.	2010	Does not include a control group
2	Singh et al.	2018	Does not measure the survival rate

Flowchart 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart for study selection



Mobility was assessed in two studies.[7,8] Park et al. reported a mean periotest value of 0.50 ± 2.77 for acid-etched OMIs and 0.28 ± 3.36 for machined surface OMIs,[8] while Moghaddam et al. did not quantify the overall mobility and he determined mobility by visual examination.[7]

Insertion torque was assessed in three studies.[7,8,11] Two of the studies[7,8] reported no significant difference in insertion torque between the surface-treated and nontreated OMIs. Chaddad et al. reported that the insertion torque statistically influenced the survival rate of the OMIs ($p < 0.05$), and it was significantly higher for the surface-treated group.[11] The mean insertion torque values ranged from 12.1 ± 6 to 13.6 ± 5.9 and 12.4 ± 5 .7 to 13.3 ± 4 for the experimental group and the control group, respectively.

Removal torque was assessed in two studies,[7,14] and both studies reported higher values in the surface-treated group. Pain and inflammation were assessed in one study, and it was reported that 80% of patients had negligible to mild postoperative pain.[11]

Discussion

Summary of Evidence

Anchorage plays a crucial role in orthodontics, and OMIs are widely popular for providing absolute anchorage with innumerable advantages. One such advantage is their versatility; they can be placed in various anatomical locations to perform different types of tooth movements. The overall success rates of OMIs, as mentioned in the literature, are high, but still, a failure rate of 10–15% has been reported.[4] Various modifications in the design and structure of OMIs have been tried to improve the survival rates, and one such method is a surface treatment. In the current review,

Table 4: Risk of bias assessment with Cochrane ROB-1 tool for RCTs

Author	*Random sequence generation*	*Allocation concealment*	*Blinding of participants and personnel*	*Blinding of outcome assessment*	*Incomplete outcome data*	*Selective reporting*	*Other bias*
Moghaddam et al., 2021	+	+	+	?	+	+	+
Park et al., 2018	+	+	+	?	+	+	+
Manni et al., 2022	+	+	+	?	+	+	+
Hammad et al., 2017	+	+	?	?	+	+	+

Table 5: Newcastle-Ottawa scale for ROB assessment of nonrandomized studies

Studies	*Chaddad et al., 2008*	*Calderon et al., 2011*	*Bratu et al., 2014*
Selection	**	**	*
Comparability	*	*	*
Exposure	**	*	**
Overall	*****	****	****
Assessment	Fair	Poor	Poor

randomized controlled clinical trials and prospective controlled clinical trials assessing the survival rates of surface-treated OMIs were only included. On analyzing the included studies that there was a moderate level of evidence to conclude there the survival rates of surface-treated OMIs were higher than nontreated OMIs. No differences in insertion torque and mobility were noted for surface-treated OMIs. Significant differences were noted in the removal torque values, and it was higher for the surface-treated OMI group. In terms of subjective symptoms like pain and inflammation, negligible differences were only evidenced.

Four out of the seven studies were RCTs, and they had a moderate ROB.[7–10] Hammad et al. did not report the blinding of participants or the observer.[9] None of the studies mentioned the method of outcome assessment.[7–10] Chaddad et al. did not report on the confounders adjusted in their study, nor the dropouts.[11] The most important limitation of Calderon's study was that groups had not been clearly defined.[12] Moreover, two RCTs of the four RCTs included in the analysis were only single-blinded RCTs.[7,8] Bratu et al. conducted the study with only male patients,[14] and Hammad et al. included only female patients.[9] Calderon et al. and Chaddad et al. specified that they had provided post-op instructions and also prescribed chlorhexidine mouthwash which could have considerably reduced post-op inflammation, thus promoting the success rate of the implants.[11,12] The anatomical location and inflammation of peri-implant tissue have been shown to affect the survival rate.[15] Poor oral hygiene results in localized inflammation of the surrounding peri-implant tissue, which is also a possible explanation for the failure rather than only immediate function.[15]

In the study by Park et al.,[8] OMI was used for various tooth movements, whereas the other studies solely did retraction or distalization of the arch. Predrilling was done prior to implant placement in the study by Chaddad et al.[11] Regarding force-delivering components, one study used a power chain for retraction, another study did not define it[14] whereas all other studies used closed nickel-titanium (NiTi) coil springs for retraction. The time of loading the implants varied between the studies of Chaddad et al. and Bratu et al. did immediate loading of implants, whereas the other authors did implant loading 2–6 weeks after implant insertion; the average load used was 150–250 gm across the studies.[11,14] In their study, Hammad et al. started retraction immediately after bicuspid extraction to utilize the rapid acceleratory phenomenon; this may have influenced the stability of implants, which was not discussed about.[9]

For assessing the stability of OMI, methods like resonance frequency analysis (RFA), periotest, and radiographic examination are used. Periotest is an electronic instrument for the quantitative measurement of the damping properties of the periodontal ligament surrounding a tooth in order to determine a value for its mobility.[16] A noninvasive gold standard method to measure stability is the RFA wherein there is a small transducer attached to an implant. For measuring stability, it has proved to be a reproducible and highly repeatable system. The transducer is excited by a steady-state signal, and its response is measured. The studies included in the current review did not evaluate mobility with RFA.

Suden et al. reported that despite the good diagnostic precision of the radiographic technique, the probability of predicting clinical instability of the implant based on radiological examination was low.[15] Moghaddam et al. evaluated the stability of OMIs by manually checking if the mobility of the OMI was >1 mm.[7] Likewise, Chaddad et al. and Park et al. defined failure of stability of OMI when there was clinically detectable mobility or presence of peri-implant inflammation.[8,11] Only one study assessed the retrieved implants using SEM and concluded the presence of bone fragments around the implant surface, ensuring good secondary stability. On that account, the results obtained from the above studies have to be interpreted carefully.

It has been reported that the risk for orthodontic mini-implant failure was highest immediately after placement.[16] The studies analyzed revealed that the mobility of OMIs checked at differing time intervals. Moghaddam et al. evaluated mobility at 3, 6, 10, 14, and 18 weeks,[7] whereas Park et al. evaluated mobility immediately after OMI insertion and 6 months after insertion.[8] Chaddad et al. evaluated the same at 7, 14, 30, 60, and 150 days.[11]

Table 6: Characteristics of the included studies

Author/year/ type of study	*Participants*	*OMI used*	*Number and area of placement of MS*	*Loading force on mini-implants*	*Outcomes assessed, statistical analysis*	*Statistical analysis and results*	*Inference*
Moghaddam et al.; 2021 (single-blinded split-mouth RCT)	62 implants in 31 orthodontic patients (eight males, 23 females; mean age of 18.5 years). Group I—sandblasted, etched group (N = 31) Group II—control group (N = 31)	Dual-top anchor system, 1.6 × 10 mm length, Jeil Medical Co, Seoul, Korea.	Placed between the second bicuspid and the first molar bilaterally.	250 gm of load was used after 6 weeks of insertion; traction was done on a 19 x 25 SS wire.	Mobility, insertion, and removal of torque. At 3, 6, 10, and 14 weeks and then in a 4-week interval.	The survival rate was 90.3 and 83.9% for the experimental group and control group, but not statistically significant ($p > 0.05$). Removal torque was higher for the sandblasted group ($p < 0.05$). Implants in younger patients showed a lower survival rate ($p < 0.05$) in both groups.	Surface treatment did not influence the survival rate of OMIs.
Park et al., 2018 (single-blinded, split-mouth, randomized, controlled trial)	98 OMIs (13 men and 27 women, (49 acid-etched and 49 machined surface) Group I—no surface treatment (OSSH1606; Osstem Implant, Busan, Korea). Group II—acid-etched surface (OSSH1606HE; Osstem Implant, Busan, Korea).	Self-drilling mini-screws (diameter 1.6 mm, thread length 6 mm) were used.	Between the second bicuspid and the first molar bilaterally.	100–200 gm of orthodontic force approximately 4 weeks after surgery. Tooth movements attempted: Anchorage for *en masse* retraction, total arch distal movement, and intrusion of posterior maxillary teeth.	Mobility and implant retention for a minimum of 6 months. Primary stability—mean insertion torques and Periotest values. Retrieved implants subjected to SEM AT 50 and 1000× magnifications.	STATS: Kaplan-Meier method, ANOVA, Kolmogorov-Smirnov test for normality. Respective success rates for group II, and I were 91.8% and 85.7%, without any statistically significant difference. Mean insertion torques were 13.62 ± 5.95 Ncm for group II and 13.38 ± 4.0 Ncm for group I Periotest: Immediate: 0.50 ± 2.77 for group II and 0.28 ± 3.36 for group I 6 months postop: 4.58 ± 5.15 for group II and 6.42 ± 5.6 for group I with an insignificant *p*-value. Acid-etched surface and en masse retraction anchorage were associated with better success rates.	No significant difference, but a high possibility of implant failure in open-bite patients or in whom distalization is attempted.
Karim Chaddad; 2008	32 mini-implants placed in 10 patients (17 machined and 15 sandblasted). Aged between 13 and 65 years.	Dual-Top (Jeil Medical Corporation, Seoul, Korea) self-tapping, threaded mini-implant diameters of 1.4, 1.6, and 2.0 mm and in lengths of 6.0, 8.0, and 10.0 mm.	Location site chosen according to the tooth movement required.	Immediately loading with a NiTi coil spring; force of 200 g and increased to 250 g after 2 weeks of healing. Tooth movements—molar intrusion or uprighting, Anterior teeth retraction or posterior teeth protraction.	Statistical analysis—Chi-squared test. Insertion torque, post-surgical pain, inflammation.	Overall survival rate—82.4 and 93.4% respectively for machined implants and acid etched mini-implants.	Implant dimensions did not influence the survival rate. Although two-thirds of the failing mini-implants were MT, the survival rate was not significantly influenced.
Calderon et al., 2011, PCCT	24 OMIs in 13 healthy patients	3M Unitek—IMTEC acid etched and sandblasted implants of length 6, 8, or 10 mm according to the anatomical site.		Loaded with 150 g of force bilaterally with a closed NiTi coil spring after 4 weeks of mini-implant placement.	Displacement of implant assessed with occlusal radiographs. Change in implant angulation with Symmetroscope millimeter grid. SEM analysis of the retrieved implants.	Stats—analysis of variance test. Anterior maxilla: 13.3% had an angular displacement up to 1°, and 6.7% were displaced 2° Posterior maxilla: 20% showed 1° rotation, 13.3% up to 2°, and 26.7% 2°. SEM—bone fragments were found embedded in the treated surface, creating new bone fibers and lamellar bone around the implant, with secondary stability.	100% survived the clinical trial. 65% implants showed <1° rotation and 35% implants showed greater than 2° rotation.

Contd…

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Author/year/ type of study	*Participants*	*OMI used*	*Number and area of placement of MS*	*Loading force on mini-implants*	*Outcomes assessed, statistical analysis*	*Statistical analysis and results*	*Inference*
Manni et al, 2022; Split mouth RCT	39 patients Group I—untreated—39 implants. Group II—treated implants—39 implants.	39 patients (23 females and 16 males, mean age—15.55 ± 7.91) (1.2 to 1.4 mm diameter implants in both the groups). Mean duration—9.3 months.	Between bicuspid and molar.	Load was applied with an e-chain from the OMIs to the button attached on the canine.	Failure rate, retention.	Statistics—generalized linear mixed effects model. No significant difference between the treated and the untreated group.	No significant difference
Bratu et al, 2014 (PCT)	A total of 40 implants were placed. Group A: treated, Group B: Chemically treated.	40 implants 10 mm in length, 1.6 mm in diameter (MIS Implants Technologies Ltd.)	Anterior or posterior region in the mandible.	Immediately loaded with 250 g of force.	Removal torque with a torque wrench.	Greater removal torque in chemically treated group offering better secondary stability.	All the implants survived the trial. Chemically treated implant group offered better secondary stability.
Hammad et al, 2017 (RCT)	45 MIs were placed on 27 patients.	1.8 mm diameter and 8 mm length (Ti-6Al-4 V) were divided into—27 MIs with surface treatment by anodization technique while the other 27 were with smooth surface (group II).	Site: roots of maxillary second bicuspid and first molar at the mucogingival junction on both sides of each patient.	Loading after 2 weeks of implant placement (NiTi coil springs) 200 g force per side for enmasse retraction.	Stats: McNamara test, Statistica software.	In group I, 22 (81.5%) OMIs presented long-term stability, while in group II, only 18 (66%) mini-implants were stable throughout the treatment. *p*-value = 0.031.	Anodized surfaces showed better stability than the control group.

Limitations

Limitations of this review include a limited number of well-designed *in vivo* studies and variability in the time period of assessment of survival rates of the included studies.

Conclusion

From the results of this systematic review, it can be concluded that surface treatment of OMIs did significantly improve the survival rates. A significant increase was noted in the torque values of the surface-treated OMI group denoting enhanced secondary stability of the OMIs, but the results of the review should be interpreted with caution as the quality of the studies included was moderate. Therefore, further well-designed RCT studies are recommended.

Clinical Significance

Better survival rates of OMIs can be expected with surface treatment, and hence we recommend surface treatment of OMIs with methods like sandblasting, acid etching, or anodization.

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