A Meta-analysis of Clinical Studies to Estimate the 4.5-year Survival Rate of Implants Placed with the Osteotome Technique

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Purpose: *To estimate the survival rate of implants placed with the osteotome technique by means of a systematic review.* ***Materials and Methods:*** *The literature was searched using Medline; the search was limited to the years 1953 to 2005. Inclusion criteria were:* (1) *clinical studies or clinical reports investigating the osteotome technique for dental implantation and* (2) *control or test group(s) from clinical studies or clinical reports, even if they did not fit with other criteria. By pooling the data of the included studies, overall Kaplan-Meier survival curves were constructed for the periods before and after loading.* ***Results:*** *The initial literature search yielded 164 studies. After selection criteria were applied, 5 studies were considered suitable for inclusion. The combined data of 349 implants revealed survival probabilities of 98% (confidence interval [CI], 97.2% to 100%) until loading and 99% (CI, 94% to 100%) after 56 months of loading. At the end of the observation period 41 implants in 18 patients were still at risk.* ***Conclusion:*** *The outcome of dental implantation using the osteotome technique in terms of implant survival seems to be similar to that of implants placed by means of the conventional implantation technique.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:110–116

Key words: *dental implants, meta-analysis systematic review, osteotome technique*

Over the years, many different implant systems have been introduced, with substantial variations in drilling equipment. Amongst others, surgical technique is considered to be 1 of the factors of importance for successful osseointegration of dental implants.[1–6] Biological failures of oral implants have been associated with bone quality and the degree of surgical trauma.[7,8]

One of the surgical techniques that has been introduced is the osteotome technique. This technique and the instruments used to perform it are defined in the literature, although the terminology used to describe them has been inconsistent. Tatum[9] (1986) designed a set of "socket formers," which is actually a series of graduated wedges. According to the author, these formers can be used to aid socket preparation by means of progressive compression of bone and will in this way form the internal configuration of the socket.[9]

Later, Summers[10] (1994) was the first to present a complete implant site preparation technique in which the bone is compressed rather than removed; he called this the "osteotome technique." The objective of this technique is to maintain, if possible, all of the existing maxillary bone by pushing the bone aside with "minimal trauma" while shaping the osteotomy accurately.[10]

When reviewing the literature few data were found on the predictability of osteotome technique without additional sinus elevation or ridge expansion.[11–14] It appears that in the majority of clinical studies, the osteotome technique was done in combination with sinus floor elevation (SFE) or guided bone regeneration (GBR).

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The main purpose of the osteotome technique is to form a denser bone area around the prepared site, thus enhancing the effective bone quality around the implant. However, it is not completely clear how the use of this technique affects the healing process. For instance, the magnitude of forces and the amount of heat generated by "hammering" the implant site with an osteotome, as well as the role that these features play in the healing process, are unknown.

During the last few years, ex vivo models have been used to demonstrate the efficacy of the osteotome technique. In contrast, Buchter and associates demonstrated significantly higher removal torque values for conventional technique compared to osteotome,[15] while Shalabi and associates[16] showed only a significant difference between osteotome technique and a so-called undersized preparation technique, where diameter of implant bed is smaller than the implant diameter; removal torque values were 51 and 103 Ncm, respectively.[16]

In addition to ex vivo studies, in vivo animal studies have also been carried out. Some of these experiments showed significantly higher removal torque values and bone ratios after 28 days healing for conventional techniques compared to the osteotome technique.[17,18] Nkenke and associates,[19] however, found a significant increase in bone-to-implant contact for the osteotome technique compared to a conventional technique after 2 and 4 weeks of healing. At 8 weeks, this significant difference no longer existed. Also, immediately loaded implants placed with the osteotome technique performed the same as implants subjected to an unloaded healing period prior to loading. No statistical difference in bone-to-implant contact was observed between the loaded and unloaded approaches in studies where the osteotome technique was used.[19–21]

The currently available experimental data do not provide a clear answer on the value of the osteotome technique. It is also known that in vitro, ex vivo, and in vivo animal data are very difficult to extrapolate to the human clinical situation. This is caused by various discrepancies, eg, differences in loading conditions, bone density, and healing times. Fortunately, several clinical studies have been done in which the osteotome technique was used for the placement of oral implants in the maxilla. The aim of this study was to systematically review the data from reported clinical studies regarding the osteotome technique with the purpose of estimating the overall survival rate of implants by means of a meta-analysis.

MATERIALS AND METHODS

The major phases in this review were literature search and selection, inclusion/exclusion of papers, extraction of data, and statistical analysis. The literature was searched with an electronic database (Medline) with year limits of 1953 to 2005. The last electronic search was conducted in December 2005. The key word used was "osteotome." Two independent readers read the abstracts of the articles found. Studies dealing with dental implants and the osteotome technique were included. Control or test groups in which the osteotome technique was used were included, even if they did not fit with other criteria (ie, did not involve use of the osteotome technique). However, descriptive studies (ie, preliminary reports, case reports, pilot studies) and systematic reviews were excluded. If no abstract was available in Medline, the original article was used. Disagreements were resolved by discussion.

In the second step, article selection was further refined. Two readers selected articles on the basis of an additional list of selection criteria. The literature selected was limited to clinical studies or clinical reports in which the osteotome technique was used with dental implants. Studies in which the osteotome technique was used for implant site preparation with or without sinus floor elevation were included.

Next, the reference lists of included papers were checked by hand and cross-matched with the original list of references with the purpose of adding papers that met the inclusion criteria but had been overlooked.

The selection procedure was completed by independent reading (2 readers) of the aims, Materials and Methods sections, and Results sections of the articles. Cohen's kappa coefficients were used as a measure of agreement between the 2 readers for both selection steps.

Overall cumulative Kaplan-Meier survival curves were constructed for the periods before (S_u = survival of implants before loading) and after loading (S_l = survival of implants after loading). The end point of S_u was used as the starting point of S_l (S_l = 100%). Standard error (SE) was computed with the Greenwood formula and confidence intervals with ± 2 standard errors. Implants that did not fail at the end of a study observation period were considered censored observations.

Survival data from the selected papers were only extracted and used for inference in studies where the osteotome technique was used for implant site preparation with or without sinus floor elevation. Data from articles in which this technique was used for sinus floor elevation only were not included.[22–24]

For the most part, the description of the osteotome technique by Summers[10] was applied to the selected

Table 1 Selected Papers

Study	Year published	Reason(s) for exclusion
Barabolia[26]	1972	Explanatory and illustrative study
Buchter et al[18]	2005	In vivo animal study
Buchter et al[15]	2003	In vitro study
Flanagan[27]	2002	Explanatory and illustrative study
Fugazzotto[25]	*2002*	—
Fugazzotto and De[28]	2002	Implants placed in regenerated bone
Hahn[29]	1999	Explanatory and illustrative study
Komarnyckyj and London[30]	*1998*	—
Nkenke et al[20]	2005	In vivo animal study
Nkenke et al[19]	2002	In vivo animal study
Rodoni et al[31]	*2005*	—
Strietzel et al[32]	*2002*	—
Summers[10]	*1994*	—

Papers remaining after second selection are presented in italics (n = 5).

studies; that description is "a complete implant site preparation technique, in which the bone is also not removed but compressed." One selected study used a different surgical approach consisting of the use of a calibrated trephine drill followed by an osteotome.[25]

RESULTS

The Medline literature search resulted in 164 hits. After the first selection step, 13 articles remained[10,15,18–20,25–32] and 151 had been excluded (interreader agreement $\kappa = 0.74 \pm 0.09$). The second step revealed 5 papers[10,25,30–32] that fulfilled the inclusion criteria (interreader agreement $k = 0.84 \pm 0.14$). Eight papers were excluded in this step: Three studies were explanatory and illustrative, 3 presented in vivo animal studies, 1 described an in vitro study, and 1 clinical study investigated implants placed in regenerated bone. The hand search did not reveal additional studies to be included (Table 1).

Although the selected studies showed a substantial variation in study characteristics and differences in reporting quality (Table 2), sufficient information was provided for statistical analysis. The 5 studies

Table 2 Relevant Data Regarding the Selected Clinical Studies

	Fugazzotto[25] (2002)	Komarnyckyj and London[30] (1998)	Rodoni et al[31] (2005)	Strietzel et al[32] (2002)	Summers[10] (1996)
Prospective/retrospective	Retrospective	Prospective	Retrospective	Retrospective	Clinical report
Patient selection criteria given	Yes	Yes	No	No	No
No. of patients	103	16	48	22	55
Male/female	42 M (40.8%)/ 61 F (59.2%)	NA	25 23	10 M/12 F	NA
No. of implants	116	43	134 (41)*	22†	143
Implant system	3i/Implant Innovations (Palm Beach Gardens, FL) and Straumann (Basel, Switzerland)	Straumann	Brånemark (Nobel Biocare) Göteborg, Sweden) and 3i/Implant Innovations	3i and Friadent (Dentsply Friadent Ceramed, Lakewood, CO)	Microvent (Dentsply) + Integral + Hexcylinder (Calcitek)
Implant surface	NA	TPS	Turned (machined)	NA	HA + TPS
No. of operators	1	NA	2	NA	NA
Bone type(s)	NA	3 and 4	NA	2 and 3	4
Implant length (mm)	NA	NA	10, 11.5, 13, 15	NA	≥ 13
GBR	With + without	With + without	Yes	NA	NA
SFE	Yes	With + without	Yes	NA	NA
Postoperative management	Described	Described	NA	NA	NA
Healing period	6 to 12 wk	≥ 9 mo	6 mo	6 mo	≥ 8 mo
Loading time (mo)	For 31 implants, 0 to 12 mo; for 43, 13 to 24; for 29, 25 to 36; for 11, 37 to 48	9 to 48 mo	9 to 80 mo	3 to 12 mo	11 to 27 mo
Loading type	Single crown, fixed partial denture, abutment	NA	NA	NA	NA
Reasons for failure/removal given	No	Yes	NA	Yes	No
Complication described	3 sites	1 patient	NA	3 patients	1 implant
No. of implant failures	2	2	0	2	2

*Number of patients in which the osteotome technique was used given in parentheses.
†Only 12 implants loaded.

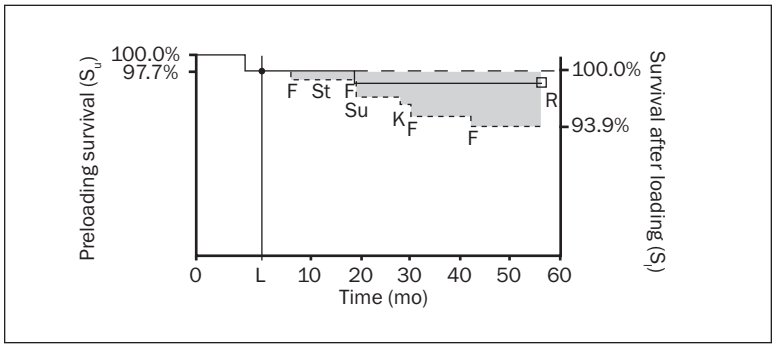

Fig 1 Survival probabilities of the implants with 95% CIs. F = Fugazotto[25] (4 groups, each with a different loading period); K = Komarnyckyj and London[30]; R = Rodoni et al[31]; St = Strietzel et al[32]; Su = Summers.[10] • Endpoint of preloading period (S_u) (97.7% survival; healing period minimum 6 weeks) and starting point of loading (S_l) (no. at risk = 349). Open box = Endpoint of loading period (98.8% survival, no. at risk = 41). Gray shading = CI. Red line = Lower confidence interval (endpoint 93.9% survival).

Table 3 No. of Implants at Risk and 95% CIs Censoring Time After Loading

Study	Year published	Mo	Implants at risk	95% CI
Baseline		0	349	0
Fugazzotto[25]	2002	6	318	(0.99;1)
Strietzel et al[32]	2002	13	306	(0.99;1)
Fugazzotto[25]	2002	18	263	(0.99;1)
Summers[10]	1996	19	122	(0.97;0.99)
Komarnyckyj and London[30]	1998	28	81	(0.96;0.99)
Fugazzotto[25]	2002	30	52	(0.95;0.99)
Fugazzotto[25]	2002	42	41	(0.94;0.99)
Rodoni et al[31]	2005	56	41	(0.94;0.99)

used the osteotome technique as defined (although it must be noted that Fugazzotto[25] used a somewhat different approach); therefore all data were used for the construction of the cumulative overall survival curve. Since the studies presented a range of follow-up times, only mean follow-up periods could be used as censoring times. The endpoints of S_u (time until loading) and S_l (after 56 months) were respectively 98% (CI: 97.2% - 100%) and 99% (confidence interval [CI]: 94% - 100%) (Fig 1 and Tables 3 to 5).

DISCUSSION

The current study deals with a systematic review. Data from clinical studies were combined in order to determine an overall survival rate of dental implants placed using the osteotome technique.

The selection procedure started with a broad search strategy. Because of the use of a single data source (Medline), there was a chance of selection bias. To overcome this problem, the reference lists of included articles were hand searched. Since no additional papers were found that met the inclusion criteria, it was considered unnecessary to search other databases.

All selected clinical studies except 1 used the osteotome technique as described by Summers.[10] Fugazzotto[25] described the use of a calibrated trephine bur in the first step in the procedure, mentioning that this method is less traumatic and disconcerting to the patient compared to repeated malleting. Next, a calibrated osteotome corresponding to the diameter of the trephine was used to push the trephined bone core in the direction of the sinus floor. Finally, implant site preparation was completed using sequentially sized osteotomes. According to the author, the use of a trephine before the osteotome reduces the loss of significant amounts of bone compared with the use of spiral pilot drills. Although this surgical technique was considered substantially different from the techniques described in the other selected papers, it is still in line with the definition used in this study for osteotome technique. Furthermore, it must be noted that 2 different implants and 4 different loading groups were used in this study. The results were reported only in relation to loading; data were not handled independently for each implant system.

Unfortunately, no systematic reviews are available which deal exclusively with maxillary implants. Therefore, the results of the current meta-analysis were compared with other clinical reviews which contained mixed populations (ie, both mandibular and maxillary implants). The comparison indicated that the present findings are within the range of

Table 4 Details of Implant Failure of Selected Studies

Study	No. of implants	No. of implants for which osteotome technique was used	No. of implants that failed before loading	No. of implants that failed after loading	Implant risk period	Mean follow-up period (mo)*	No. of implants excluded by author (reason)
Fugazzotto[25] (2002)	116	116	2 at abutment placement	No failure	31 implants for 6 mo; 43 for 18 mo; 29 for 30 mo; 11 for 42 mo	6, 18, 30, 42	No
Komarnyckyj and London[30] (1998)	43	43	2 at abutment placement; both replaced	No failure	43 for 28 mo	28	No
Rodoni et al[31] (2005)	134	41	—	—	18 implants for 44 mo	56	Only 1 implant from each patient included for statistical analysis (23 excluded)
Strietzel et al[32] (2002)	22	22	2	No failure	12 implants for 13 mo	13	12 evaluated; 8 dropped out or not available for follow-up
Summers[10] (1994)	143	143	2—1 during abutment connection; 1 because of infection	3 (treated)	143 implants for 19 mo	19	No

*Censoring time = follow-up time.

Table 5 Steps of Surgical Technique for Included Studies

	Steps				
Study	1	2	3	4	5
Fugazzotto[25] (2002)	500 rpm (trephine)	Osteotome	Self-tapping width 3.75 or 4	Or non-self-tapping diameter 4.1	Or non-self-tapping diameter 4.8
Komarnyckyj and London[30] (1998)	Twist drill width 2 mm	Osteotomes 1 and 2	3.5-mm-wide dilator	Osteotome 3, SE cases	Implant
Strietzel et al[32] (2002)	Pilot drilling	Osteotomes or bone condenser (Friadent)		Implant	

The surgical technique of Rodoni et al[31] was not described in detail. See the text for a description of the surgical technique of Summers.[10]

those reported in other reviews (ie, reviews evaluating different implant systems using conventional dental implantation techniques).[34,35] Eckert and colleagues[35] estimated an overall 5-year survival rate of 96% (CI, 93% to 98%) for the pooled data of 17 articles (in total 7,398 implants) and found no differences between the evaluated systems with respect to implant survival rate. However, since the present meta-analysis, as well as the outcomes of the aforementioned reviews, were based partially on cohort studies and case series and not on randomized clinical trials (RCTs) only, direct comparison of efficacies is not possible. A recently published systematic review of RCTs only provided evidence on the efficacy of different implant systems,[36] but no data regarding the osteotome technique were included. Moreover, the outcomes were presented in relative-risk ratios rather than in survival probabilities. Although the reviews to which the present results were compared[34,35] failed to provide evidence regarding efficacy, the information provided regarding clinical performance in terms of survival may be considered

evidence regarding the prognosis of the implants.[37,38] Therefore, it appears that the prognosis of implants placed in the unfavorable maxillary sinus region, as estimated in the present study, is similar to that of the mixed implant populations that were involved in the Eckert study.[35] That review included a substantial number of implants that were placed in the mandible, which is known to be a more favorable site for implantation.[39–43]

Another recent meta-analysis evaluated the survival of dental implantation following SFE with osteotomes.[44] Comparison of that review and the present one reveals that the survival probabilities were similar. The sets of studies included in these meta-analyses had 1 common primary study.[25] In another systematic review, which evaluated implants placed in grafted maxillary sinus sites,[45] the survival probability after 3 years was calculated to be 88.5% for implants with autogenous bone grafts and 95.6% when bone substitutes were used.

In conclusion, for the period investigated, the prognosis of implants placed using the osteotome technique as computed in this study seems to be similar to published data of implants placed by conventional drilling techniques. Nevertheless, no RCTs are available that deal solely with maxillary implants placed using the osteotome technique. Such trials are needed to support or refute the efficacy of the osteotome technique.

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