Failure patterns of four osseointegrated oral implant systems

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The aim of this metanalysis was to investigate possible differences in failure patterns among four different osseointegrated oral implant systems. Only systems with a supposed scientific validation, based on long-term follow-up studies, were selected for this analysis, i.e. the Brånemark system, the Calcitek Integral system, the Interpore IMZ system and the Straumann ITI system. While several prospective reports could be found on the Brånemark system, only a few retrospective investigations concerning the ITI and the IMZ systems were available. No data on the Integral system could be employed. Despite these limitations, a substantial difference in failure patterns among various implant systems was observed. The Brånemark implants showed a higher incidence of early failures, though sharply decreasing over time. On the contrary, IMZ implant characterized by rougher surfaces displayed a lower incidence of early failures, but showed constant or increased failure rates over time. For the ITI implants, for example, a higher prevalence of late failures, attributable to chronic bacterial infection (peri-implantitis), was observed when compared to the Brånemark system. With the exception of the latter implant system, prospective long-term follow-up studies, using similar and well-defined success criteria, are needed for the others to confirm the current preliminary findings.

1. Introduction

The concept of osseointegration [1] has considerably improved the long-term success rates of endosseous oral implant treatment [2]. Based on the predictable results obtained with machined, titanium implants (Brånemark system) [3–5], nowadays osseointegrated implants constitute an accepted treatment modality in the rehabilitation of edentulous and partially edentulous patients.

More than 30 companies [6] manufacture oral implants according to the osseointegration concept, today. These different implant systems are characterized by differences in designs and materials, surface coatings and roughness as well as in surgical and prosthetic procedures. It is reasonable to believe that these differences may influence the tissue response around the implanted devices and the long-term clinical outcome.

However, in contrast to the extensive and detailed information available from follow-up of hip and knee arthroplasties (for instance the Swedish knee arthroplasty [7] and total hip replacement [8] registers), the reports on success and failure of oral implants are often issued separately by the implant manufacturers. Among the exceptions are a few interim reports [9–11], from a long-term, randomized, prospective, multicentre study, aimed at investigating the influence of implant design, application technique, and site of placement on the clinical success, published by the Dental Implant Clinical Research Group in collaboration with the Department of Veterans Affairs Medical Centers.

Reports indicating differences in failure patterns among different implant systems have been presented [12–14]. However, more precise information is needed in order to understand better the correlation between implant characteristics and the clinical performance of any inserted device.

Failures can be defined as the inadequacy of the host tissues to establish (early failures) and/or to maintain (late failures) osseointegration [14]. Among late failures, overload in relation to unfavourable anatomical conditions and bacterial plaque accumulation (peri-implantitis) are often recognized as the major etiological factors responsible for implant losses [14–17].

Ideally, using a metanalytic approach, data from different long-term follow-up studies should be amenable to pooling so that additional and more detailed conclusions could be drawn. It is also reasonable to

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believe that implant systems, which have received full or provisional acceptance from the American Dental Association (ADA) [6] are those, which have more published data for validating their performances [18].

The aim of this metanalysis was to compare long-term follow-up studies of different implant systems with a scientific validation in order to scrutinize possible differences in their failure pattern.

2. Materials and methods

Based on the conclusions by Eckert *et al.* [18], who analysed the literature supplied by six invited implant manufacturers, chosen because of either ADA acceptance (five implant systems) or large market share (one implant system), four implant systems were selected for validation (Brånemark system, Calcitek Integral, Interpore IMZ and Straumann ITI).

Evaluation of the ITI implants was specifically difficult due to the large variety of different designs employed, some of which are no longer in production. Because of this problem, it was decided to evaluate only the titanium plasma-sprayed (TPS) solid screw, which seemed to create less problems than the hollow-basket design with vents [12, 19–21].

The basic characteristics of these implant systems are as follows.

The Brånemark implant is a solid screw made of machined commercially pure titanium. It is a two-stage system, i.e. the implant is covered by a muco-periosteum flap during the healing period. It can be applied in all clinical situations.

The TPS implant is a solid titanium screw coated with a titanium plasma-sprayed layer to increase the surface area. It is a one-stage system mainly used in the mandible. Often, these implants are immediately loaded.

The IMZ implant is a titanium cylinder coated either with plasma-sprayed titanium or hydroxyapatite. It is a two-stage system used in all clinical situations and is characterized by a flexible intramobile element (IME), which serves as shock adsorber.

The integral implant is a titanium cylinder coated with hydroxyapatite. It is used in all clinical situations as a two-stage system.

In the present study, long-term follow-up reports regarding the four systems, published up to February 1997, were collected and analysed. The information considered to be relevant was number and type of inserted implants, mean and range of follow-up period, location (mandible/maxilla), minimal failure criteria (implant mobility and/or the presence of peri-implant radiolucency), number of failures distributed between anatomical locations and chronological order (early and late losses). In the case of late failures, losses attributed to progressive incurable marginal infections were included in the "peri-implantitis group", when possible. The remaining failed implants were, on the other hand, included in the "overload group" [14]. "Mechanical" and "iatrogenic" failures, i.e. implants, which had fractured or were not used as support for abutments ("sleeping implants"), were not accounted as "biological" losses and were excluded from the calculations. Implants inserted in bone grafts were not included.

3. Results and discussion

In order to get a provisional and full acceptance from the ADA, two independent 3 and 5 year prospective studies, including a minimum of 50 patients with a minimum success rate of 85%, have to be presented [6]. All the implant systems considered in this review had received provisional or full ADA acceptance. Therefore, published data with the above-mentioned characteristics were searched and analysed with respect to possible factors contributing to implant losses. Four prospective [3–5, 22] and three retrospective [23–25] follow-up studies providing 5 year results, as well as three long-term prospective studies (two with a follow-up from 11–15 year [26, 27] and one from 3–15 year [28]), were found regarding the Brånemark system. No prospective study with similar characteristics was published up to February 1997 on the other implant systems analysed in the current investigation. Four retrospective clinical studies were found on the IMZ system in the TPS configuration [12, 29, 30, 31] providing information which could be used for this investigation. For the ITI system, six studies were found [12, 20, 32–35]. No acceptable study was found for the Integral system. All remaining investigations had to be excluded because success criteria were not properly defined or because of lack of detailed data, which could have permitted any comparison.

Data presented in Table I permit an adequate comparison between the ITI (in the TPS configuration) and the Brånemark implants, being used in the same clinical situation, i.e. the edentulous mandible. The percentage of failures was very similar in both groups (5.4% versus 5.2%, respectively), both for early (3.4% versus 3.2%) and late (2% versus 2%) losses, respectively. However, the follow-up period for the ITI system was shorter (45 months) than for the Brånemark system (9.5 years).

The compared failure patterns of the Brånemark and IMZ systems, used in different clinical situations, can be observed in Table II. The mean follow-up period for the IMZ system (2.6 years) was approximately half that for the Brånemark system (all implants followed up to 5 years). However, this did not influence in a relevant way the early failure rates, even though all of the IMZ implants were not actually followed up to 1 year. Of the Brånemark implants, 5% were reported to fail up to the 1 year control versus 0.8% of the IMZ implants. More failures occurred in maxillas than in mandibles for both systems, even though a higher percentage of Brånemark implants was placed in maxillary cases (48% versus 36%). The loss of Brånemark implants, however, sharply decreased over a 5 year period, whereas the opposite trend was observed for the IMZ system [29].

Table III presents a calculation of the prevalence of losses attributed to peri-implantitis from the few investigations in which this distinction was presented. Of the total losses occurring in the Brånemark system

TABLE I Summary of clinical studies reporting the failure prevalence of two osseointegrated oral implant systems (Brånemark and ITI systems) used in totally edentulous mandibles between the mental foramina. After insertion, the Brånemark implants were left submerged for 3 months before a second operation (two-stage system). Conversely, the ITI (TPS) implants (one-stage system) were, in most of the cases, immediately loaded

System	Reference	Inserted/ failed implants	Early/late failures	Prosthetic rehabilitation	Range/mean follow-up period
ITI(TPS)	Babbush *et al.* [32][a]	1739/103	65/38	Mainly overdentures	1–96 mon/32.6 mon
	Wedgwood *et al.* [33]	29/0	0/0	Mainly overdentures	8–48 mon/22 mon
	d'Hoedt and Schulte [12]	60/8	8/0	Overdentures	3–39 mon/17.2 mon
	Salonen *et al.* [20]	122/3	3/0	Overdentures	1–5 y/32 mon
	Leimola *et al.* [34]	153/13	4/9	Overdentures	3–10 y/5.6 y
	Chiapasco *et al.* [35]	380/6	4/2	Overdentures	6–13 y/8.6 y
	Total	2483/133	84/49		1 mon–13 y/45 mon
	(%)	5.4	3.4/2.0		
Brånemark	Lindquist *et al.* [26][b]	272/3	2/1	Fixed and overdentures	12–15 y/13.6 y
	Zarb and Schmitt [27]	233/32	21/11	Fixed	11–15.5 y/13.2 y[e]
	Zarb and Schmitt [28][c]	132/5	3/2	Overdentures	3–13 y/8 y[e]
	Jemt *et al.* [4] [d]	393/14	7/7	Overdentures	5 y
	Total	1030/54	33/21		3–15 y/9.5 y
	(%)	5.2	3.2/2.0		

[a]An unspecified number of implants were also inserted in the maxilla.
[b]Additional three implants were lost after 15 years function.
[c]17 implants were placed in the maxilla.
[d]170 implants were originally kept sleeping at initial overdenture placement.
[e]Mean of the follow-up period not provided by the authors; the figures are artificially calculated as the mean of the range values.

TABLE II Incidence of failed implants distributed over a 5 year period for two osseointegrated oral implant systems (Brånemark and IMZ mainly in the TPS configuration) used in various clinical situations. The mean follow-up period was 5 years for the Brånemark implants and approximately 31 months (2.6 years) for the IMZ

System	Reference	Total no of inserted/ failed implants		No and timing of failures					
				Before loading	1y	2y	3y	4y	5y
Brånemark	Zarb and Schmitt [40]	262/29	(TE)[a]	21	1	5	1	1	0
	Jemt and Lekholm [23]	259/7	(PE)	4	1	0	0	0	2
	Lekholm *et al.* [3]	558/36	(PE)	20	3	8	2	0	3
	Jemt [24]	449/31	(TE)	15	7	6	2	0	1
	Jemt and Lekholm [25]	717/100	(TE; OV)	35	34	19	8	2	2
	Olsson *et al.* [22]	69/8	(PE)	1	4	3	0	0	0
	Henry *et al.* [5]	107/3	(SI)	1	2	0	0	0	0
	Lindquist *et al.* [26]	272/2	(TE)	2	0	0	0	0	0
	Jemt *et al.* [4][b]	510/44	(OV)	16	16	2	6	0	4
	Total	3603/260		115	68	43	19	3	12
	(%)	7.2		5.0					
	Data for maxillas only	1728/213							
	(%)	48/12.3							
IMZ	d'Hoedt and Schulte [12][c]	70/1	(OV; PE)	1	0	0	–	–	–
	Fugazzotto *et al.* [29][d]	2023/53	(TE; OV; PE; SI)	–	19	13	11	4	6
	Fugazzotto [30][e]	626/7	(TE; OV; PE; SI)	0	2	5	0	0	–
	Quiryen [31][f]	163/10	(OV)	8	0	2	0	0	–
	Total	2832/71		9	21	20	11	4	6
	(%)	2.5		1.0					
	Data for maxillas only	1046/45							
	(%)	36/4.3							

[a]PE = partial edentulism; TE = total edentulism; OV = overdentures; SI = single implants.
[b]177 implants were originally kept sleeping at initial overdenture placement.
[c]Range/mean of the follow-up period: 1 month–3.5 year/13.5 month. Also HA-coated implants were used and the most of the implants were inserted in the mandible, but detailed information was not given.
[d]Range/mean of the follow-up period: 6–60 months/33 months. The mean was artificially calculated as the mean of the range values. The number of losses at abutment connection up to 1 year were not given separately. However, in another investigation [41] based on a smaller sample from the same patient's material were reported ten early failures over 1363 inserted implants.
[e]Range/mean of the follow-up period: 6–51 months/28.5 months. The mean was artificially calculated as the mean of the range values. All these implants were inserted in regenerated bone.
[f]Range/mean of the follow-up period: 5–49 months/23.9 months.

TABLE III Distribution of implant losses attributed to peri-implantitis reported for two osseointegrated oral implant systems (Brånemark and ITI systems) used in various clinical situations

System	Reference	Total number of inserted/ failed implants		Early/late failures	Removed for peri-implantitis	Range/mean follow-up period
Branemark	Åstrand *et al.* [42]/Olsson *et al.* [22]	69/8	(PE)[a]	1/7 (3)[b]	0	5 y
	Jemt and Lekholm [23]	259/7	(PE)[a]	4/3 (2)	1 (5)[c]	5 y
	Mericske-Stern and Zarb [19]	68/5	(OV)[c]	4/1 (1)	1 (?)	5 y
	Henry *et al.* [5]	107/3	(SI)[a]	1/2 (0)	0	5 y
	Total	503/23		10/13 (6)	2	5 y
	(%)	4.6		2.0/2.6	8.7/33.3[d]	
ITI (TPS)	Salonen *et al.* [20]	122/3	(OV)[a]	3/0	0	1–5 y/2.6 y
	Leimola-Virtanen *et al.* [34]	153/13	(OV)[a]	4/9 (9)[b]	8(4–8)[c]	3–10 y/5.6 y
	Total	275/16		7/9 (9)	8	1–10 y/4.3 y
	(%)	5.8		2.5/3.3	50.0/88.9[d]	

[a]PE = partial edentulism; OV = overdentures; SI = single implants.
[b]Within parenthesis the number of failures after the first year of loading.
[c]Year of removal.
[d]The first figure represents the percentage of implant losses due to peri-implantitis in relation to the total number of failed implants, whereas the second figure refers to the percentage of losses attributed to peri-implantitis for implants failed after the first year of loading.

(4.6%), 8.7% were attributed to peri-implantitis. The corresponding value for the ITI system was 50%. After the first year of function, the percentage of losses, attributed to chronic marginal infection, were 33.3% versus 88.9%, respectively, for the two systems.

The failure pattern of Brånemark implants has recently been reviewed in detail [14]. Owing to the fact that most of the scientific data found in the literature concern the Brånemark implants [14, 18], it seems obvious to consider this system as a reference implant system. The highest number of failures in relation to the Brånemark implants are occurring during the first year of function (Table II). Thereafter, a decreased number of losses was seen over time.

Regarding the other implant systems included in this metanalysis, little scientific information was found in the literature. Nevertheless, some preliminary, although limited, conclusions can be drawn.

The ITI (TPS) system showed figures very similar to those of the Brånemark implant system (Table I). However, most of the ITI implants had been immediately loaded. This indicates that immediate loading does not substantially seem to affect rates of early losses, when implants having a rough surface are inserted in edentulous mandibles. On the other hand, the long-term performance of the ITI system has not yet been documented to the same extent as that of the Brånemark system. The highest prevalence of peri-implantitis observed for the ITI implants (Table III) might indicate a less favourable outcome over the years for this system.

The IMZ system showed fewer failures up to the first year of function in comparison with the Brånemark implants (1.0% versus 5%, Table II). No definitive conclusions can be drawn on the long-term outcome of this system yet, but failures [29] and marginal bone loss seem to increase over time [31]. In this context, the role of the intramobile element remains conjectural, lacking an adequate control group.

No data could be presented about the Integral system. However, the impression obtained from analysing the published literature was that this HA-coated system showed constant failure rates over time [36, 37]. Unfortunately, the actual number of losses related to the integral system could not be calculated, because of other success criteria (implant survival) and due to the observation that many implants were removed for "iatrogenic reasons".

One of the hypothesis to be tested was if the presence of a rough surface would have decreased the number of early failures and conversely, if this property would affect the long-term prognosis adversely, due to a higher incidence of losses attributable to peri-implantitis. In fact, rough implant surfaces have been mentioned to favour plaque accumulation, which may lead to implant failures (peri-implantitis) [38]. This might explain the constant or increased failure rates over time observed among implant systems with this surface property. Despite the fact that a clear distinction between early and late failures could not be made for all the implant systems analysed, the present findings still indicate that IMZ implants, characterized by a rough surface, show a lower incidence of early failures when compared to threaded, smooth implants.

4. Conclusion

There are, in general, very few clinical investigations of implant systems that can be used for comparative studies. This is in agreement with what has been previously published [39]. Success criteria and evaluation parameters are often mentioned, but the data are seldom published in detail. With the exception of the Brånemark system, no studies having the minimum characteristics set by the ADA for provisional or full acceptance, could be found in the literature regarding the three other implant systems analysed in this metanalysis. Prospective follow-up investigations using similar, well-defined and accepted success criteria are needed in order to confirm the preliminary findings previously described. Therefore, standardization of success criteria is an urgent requirement. The institution

of an oral implant register might prove beneficial to both implant manufactures and users in terms of quality control, and it could also provide useful information on the influence of the various implant characteristics on the clinical performance and failure mechanisms of the different implant systems.

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