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An up to 17-year follow-up retrospective analysis of a minimally invasive, flapless approach: 18 945 implants in 7783 patients

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Abstract

Background: This study investigates gender, age, jaw, implant position, loading protocol (immediate vs delayed), smoking, and type of surgery (punch vs flap) as influential factors of implant survival in a large patient collective.

Purpose: To evaluate the survival rates of implants in patients using a mucoperiosteal punch for flapless implantation in the majority of cases in order to evaluate its medical efficacy and safety.

Materials and Methods: Between 1994 and 2015 all patients with complete data treated at the Wienerberg Dental Clinic, Vienna, Austria, were included and statistically analyzed in Cox proportional hazard (PH) models. As patients with multiple implants were included, a clustering term was added to the Cox PH model to respect pooled failures in patients.

Results: Of the initial 24 282 ANKYLOS/Dentsply implants placed in 8137 patients a total of 7783 patients with 18 945 implants were finally included. The mean follow-up was 2.8 ± 3.2 up to 17.9 years. Cumulative survival rates (CSRs) after 1, 3, 5, and 10 years were 98.5%, 97.7%, 96.7%, and 93.0%, respectively. Of these, 17 517 (92.5%) implants were placed minimally invasive via a flapless approach by use of the ATP-Punch with comparable survival rates as observed for flap surgery. The Cox PH models proved smoking (hazard ratio [HR] = 2.2) and implant position as significant factors of implant survival. In the maxilla, canines and third molars were identified as low risk sites in comparison to the most frequently implanted first premolar site. In the mandible, the central incisor and second premolar were identified as high-risk sites, the canine as low risk site in comparison to the most frequently placed first molar site.

Conclusion: The analyzed data concludes the safety and medical efficacy of the ATP-Punch. The CSRs using this flapless technique are comparable to the classic surgical flap approach.

KEYWORDS
clinical study, flapless implant surgery, implant survival, long-term study, long-term survival, retrospective, survival rate

1 | INTRODUCTION

In oral implantology, osseointegration is nowadays considered to be highly predictable which is why minimally invasive surgical approaches[1] are sought in order to not only allow for proper function and good esthetic results but also for the highest possible patient comfort. Flapless implant surgery using either a tissue punch or a mini incision is a key technique to significantly reduce side effects, such as pain and swelling, hereby enhancing patient comfort considerably.[2]

Various factors have been associated with failures of dental implants. In a comprehensive review,[3] an increased implant failure rate has been suggested for a low insertion torque of immediately or early loaded implants, inexperienced surgeons, maxillary implants, implants in the posterior jaw region, heavy smokers, bone qualities type III and IV, small bone volumes, shorter length implants, greater number of implants per patient, lack of primary implant stability, cylindrical (non-threaded) implants, prosthetic rehabilitation with implant-supported overdentures, nonsubmerged implantation technique, immediate loading, implant insertion in fresh extraction sockets, and smaller diameter implants.

In a systematic review and meta-analysis[4] including 73 studies with 8241 implants, the insertion of implants in fresh extraction sockets was calculated to increase the relative risk of implant failure by 58% as compared to healed sites.

Long-term survival of implants still lacks scientific evidence. In this regard, it is especially noteworthy to refer to publications that have investigated this topic. Jemt described 25 years cumulative survival rates (CSRs) of 95.8% in maxillae and 95.1% in mandibles for single-implants, and 11-year CSRs of 98.5% and 97.2%, respectively.[5]

In a retrospective study[6] including 10 096 implants in 2670 patients, survival of dental implants placed in sites of previously failed implants was investigated. Finally, in an analysis[7] covering 11 074 operations in 8808 patients performed during 28 years, significant differences were found regarding early implant failures related to individual surgeons, surgeons' gender, type of treated jaws, and surface of implants used.

The objective of the present study was to evaluate the short-term and long-term success rates of dental implants mainly placed via a minimally invasive flapless approach in a large patient collective including subgroup analyses of factors (gender, age, jaw, position, loading protocol, smoking) presumed to have potential influence on implant survival.

2 | MATERIALS AND METHODS

2.1 | Study population

The data for this retrospective analysis were obtained from a single study site (Dental Clinic Wienerberg City, Vienna, Austria). All surgical procedures were performed in this institution by six oral surgeons. All subjects had given written informed consent prior to the respective procedure. Our retrospective study was independently reviewed and approved by the local ethics committee of the Medical University of Vienna, Austria (# EK 1007/2017).

Patients to be considered for implant surgery had been selected according to the following inclusion criteria: women and men aged 15 years or older having one or more missing teeth in the maxilla or mandible. Exclusion criteria were as follows: pregnant or breastfeeding women, poor oral hygiene, hypercortisolism, corticoid treatment, i.v. bisphosphonate therapy, subjects suffering from cancer requiring chemotherapy or those who have recently had radiation in the maxillofacial area, immune-suppressed patients, and patients with severe mental or physical disabilities inhibiting sufficient oral hygiene. Smoking or bruxism was not an exclusion criterion.

Preoperative evaluation included general anamnesis, clinical examination, and a panoramic radiograph. In cases where bone width and height appeared questionable due to anatomical structures (maxillary sinus, inferior alveolar nerve), a cone beam computed tomography scan (Planmeca ProMax 3D, Planmeca, Helsinki, Finland) was performed.

Bone associated preconditions allowing the placement of one or more implants in the maxilla or mandible using the ATP-Punch[8] were: sufficient bone quality[9] as well as sufficient height and width within atrophy class I-IV.[10] Patients were not considered for flapless implant surgery if one or more of the following bone associated limitations (under which the use of the ATP-Punch should be avoided) were present: residual mandibular alveolar ridge height of less than 9 millimeters to the inferior alveolar nerve and less than 6 millimeters in width, anatomical or pathologic reasons (Underwood septa, maxillary sinusitis, polyposis) hindering sinus-lift augmentation as preimplantologic requirement in cases of significant maxillary atrophy. The tissue associated prerequisite for flapless procedures is that a sufficient amount of keratinized gingiva should be present in and around the punch-site.

2.2 | Surgical procedure

Ankylos screw-type implants (DENTSPLY-Friadent, Mannheim, Germany) were placed using the ATP-Punch (DENTSPLY-Friadent, Mannheim, Germany) invented by Prof Dr Wolfgang Jesch. From 1994 to 2009, Ankylos Plus implants were used. From 2009 to 2013, Ankylos Plus as well as Ankylos C/X type implants were applied. Since 2013 only Ankylos C/X implants have been used. The main difference between the two implant types lies primarily in its prosthetic design from 2008 onward. In 2005, a grit-blasted and high temperature-etched Friadent plus surface was introduced. The ATP-Punch is comprised of four parts: a rotating blade (1), a shredder (2), a casing (3), and a spring (4), all assembled being the actual surgical tool (Figure 1). The ATP-Punch is connected to a conventional surgical anglepiece including the external physiological saline solution needed for cooling (Figure 2).

The surgical procedure using the ATP-Punch (which has a diameter of 3.5 millimeters) consists of the following steps:

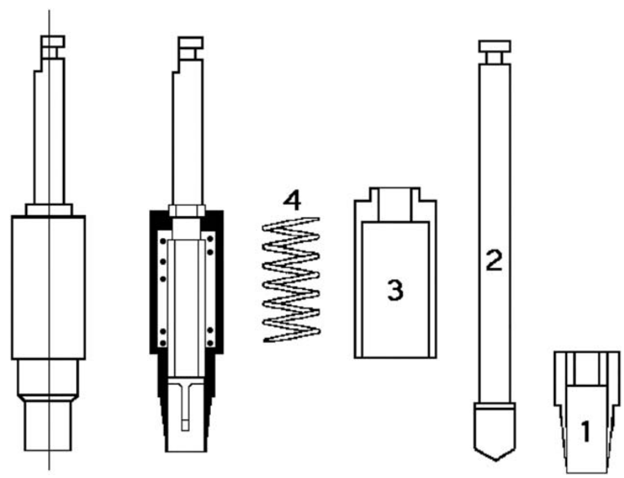

FIGURE 1 ATP-Punch comprising rotating blade (1), shredder (2), casing (3), and spring (4)

FIGURE 2 ATP-Punch connected to conventional surgical anglepiece

- Under light pressure, while rotating at approximately 2000 rates per minute (rpm) the punch pierces through the gingiva and periosteum enabling an almost trauma-free perforation of the mucoperiosteum, resulting in a circular conical plateau in the alveolar bone in either the mandible or the maxilla. As the alveolar ridge provides a natural support, only the periosteum is penetrated with a small circular hole (Figure 3A,B).
- Following this, more pressure is exerted and the built-in rotary blade is activated. The blade shreds the mucosa cylinder down to the periosteum. Arriving at the bone, further pressure is exerted under continuous physiological saline solution cooling (Figure 3C). This results in a small, circular plateau with a central notch in the bone. The bored-out, cone-shaped hole has a diameter of 1 millimeter providing an ideal prerequisite for placement of the primary drill. Peri-implant mucosa, gingival epithelium (junctional, sulcular, and oral) and soft-tissue remnants, as well as bone splinters are collected in the upper area of the punch between the rotating blade and the shredder (Figure 3D).
- The further steps of implantation (primary drill, depth and width drill, implant insertion) are those exactly like in the mucoperiosteal flap approach. No suture is required at the end of surgery.

The surgical technique detailed above as well as the bone augmentation procedures described in the following section have been available and used during the whole study period from 1994 to 2015.

2.3 | Bone augmentation and loading protocols

In cases where the remaining maxillary bone height was below 4 millimeters, a sinus lift was performed simultaneously with a two-stage procedure, that is, sinus lift and secondary implant placement. Bone augmentation material was either Ostim (Heraeus Kulzer, Vienna, Austria) or Bio-Oss (Geistlich Biomaterials, Baden-Baden, Germany). All sinus lift procedures where performed either minimally invasive using an innovative method based on high hydraulic pressure (Jeder-System, Jeder GmbH Dental Technology, Vienna, Austria[8]) or by a classic lateral fenestration technique.[11] Bone augmentation material was also added after cyst removal 3 months prior to implantation.

Apart from sinus lift procedures as described above, also socket preservation techniques and lateral block augmentation have been applied.

In all cases involving augmentation, a 3–4 months healing phase was required. After second-stage surgery, the final restorations were delivered within 1–4 weeks depending on the prosthetic solution (single-tooth crowns, bridges, implant supported dentures). Immediately loaded implants received the definitive restoration on the same day, or latest after 1 week. All provisional restorations functioned out of occlusion. All patients that required a temporary restoration were asked to minimize loads by consuming a soft diet until the definitive restoration was fitted.

In those cases, where second-stage surgery was performed a healing period of 3 months was applicable in both upper and lower jaws. In those cases, where grafting took place second-stage surgery was always performed 3 months after implant placement. Implants which were immediately loaded received either the final prosthetic solution or in few cases a provisional crown.

Edentulous patients were basically restored with removable overdentures supported by two or four implants.

From 1994 to 2004, the prosthetic treatment was performed at the Hanusch Hospital in Vienna, Austria. Since the clinic and its same employees moved, from 2004 onwards the treatment was continued at the Dental Clinic Wienerberg City in Vienna, Austria. In case of immediately loaded implants, the impressions were made on the same day of the implantation. The prosthetic solution was fixed within a maximum of a week after implant placement. From the year 2004 until 2010, the

FIGURE 3 ATP-Punch work flow, for details of preparation steps (A-D) refer to main text

prosthetic solutions were predominantly fixed through cementation. With the onset of the digitalization, we have switched to the most part to screw retained prosthetic solutions since the year 2010. Referred patients were prosthetically treated externally at the offices of referring dentists.

2.4 | Perioperative and postoperative care

Prior to surgery local anesthetic infiltration (articaine hydrochloride 4% with epinephrine 1:100.000) was administered buccally and palatally/lingually as required. Patients were instructed to rinse their mouth for at least 1 minute with 5 milliliters of 0.2% chlorhexidine gluconate. Postoperatively, patients were prescribed either Penicillin 1000 mg twice a day or Clindamycin Hydrochloride 300 mg 3 times daily, for approximately 1 week.

2.5 | Clinical and radiological follow-up

In flapless surgery cases using the minimally invasive approach without sutures, a postoperative clinical examination shortly after implantation was seldom required. Immediately after implantation a control panoramic radiograph was taken. A control CBCT scan was performed only in cases where possible postoperative complications (ie, sinusitis, peri-implantitis, paresthesia) were suspected. Patients were asked to come for recall appointments once a year. A control panoramic radiograph was taken every 2 years after implantation during recall.

The same radiographic techniques have been available and in use during the entire inclusion period from 1994 to 2015.

All implants that broke, became loose, or suffered from recurrent peri-implant infections were removed.

2.6 | Statistical analysis

The data evaluated were extracted from the Wienerberg City Dental Clinic patient database. This data is based on programming by Zimmel & Partner GmbH, Vienna, Austria using FileMaker Pro 14 (FileMaker, Santa Clara, USA). Implant data of all patients was exported into a comma separated value (csv) file. Statistical evaluation was carried out using the open source statistical programming environment "R version 3.2.3."[12]

The principal endpoint in this study was implant failure over time. The survival time was defined as time between placement and failure (ie, implant loss) or last follow-up. To determine 1-, 3-, 5-, and 10-year CSRs a Kaplan–Meier analysis was performed. Gender, age, jaw, position, loading protocol, smoking, and type of surgery (flapless surgery was compared to more invasive flap surgery) were analyzed in seven univariate Cox regression models. As patients with multiple implants were included (ie, clusters of implants), a cluster term was included into each Cox regression model clustering patients. This corrects for correlated implants under observed patients. The implant region was separately analyzed for maxilla and mandible with the predominant implant site as reference. Finally, a multivariate Cox regression model was computed to correct for multiple testing. The overall level of significance was defined to be 0.05. To correct for multiple testing, alpha splitting was applied for each of the seven Cox regression models. Thus, the significance level for each of the seven models was 0.73%.

3 | RESULTS

3.1 | Study population

In the above-mentioned database, a total number of 24 282 implants were documented over a more than 21-year period from February 1994 to November 2015. For our retrospective study, a total number of 5337 implants had to be excluded. To correct for pooled effects in patients, a clustering term for patients was added to the Cox proportional hazard (PH) models. Three thousand eight hundred and fifty implants were excluded from the outset due to missing patient IDs in the initial database ($n = 3130$), or because the implant region had not been documented ($n = 720$). As 933 patients did not have a valid documentation on their follow-up visit, 1487 implants had to be excluded. The database query, on which this investigation is founded, includes follow-up visits until 12/2016. Thus, a total number of 18 945 implants (78.0%) in 7783 patients were included for statistical analysis. Of these, 17 517 implants—corresponding to 92.5% of all implants to be included and analyzed—were placed minimally invasive via a flapless approach by use of the ATP-Punch. Both punched sites and flapped sites were more frequent in the maxilla at a ratio of maxilla: mandible = 1.17: 1 in punched and 1.22: 1 in flapped sites. There were 4642 women aged 57.7 ± 14.5 years (range: 15.0, 94.7) and 3141 men aged 58.0 ± 14.6 years (range: 16.1, 94.7). Of all finally included patients the majority (80.8%) had one surgery with one or more implants, 15.1% had two surgeries, the remaining 4.1% patients up to seven individual surgeries. In these surgeries 41.1% received one implant, 39.2% two implants, 7.2% three implants, 7.9% four implants, and 4.6% five and more implants. Little over a fifth (22.8%, ie, 1772) of the patients were edentulous ($n_{maxilla} = 537$, $n_{mandible} = 1235$) with 4722 implants ($n_{maxilla} = 2148$, $n_{mandible} = 2574$). A total of 193 (1.0%) implants had augmentation procedures including socket preservation, lateral block grafts, and sinus lift. The mean follow-up was 2.8 ± 3.2 up to 17.9. Number of patients and implants with a certain follow-up are provided in Table 1 and Figure 4. 15 patients with 41 implants had a follow-up of 15 years and more, three with five implants of more than 17 years.

3.2 | Survival rates and influencing factors

With 423 lost implants in 236 patients of the finally included 18 945 implants in 7783 patients, the overall implant failure rate was 2.2% and 3.0% on a patient level. A third of the patients with implant loss lost one implant (31.9%, $n = 135$), 13.9% ($n = 59$) two, 4.5% ($n = 19$) three, 3.1% ($n = 13$) four, 2.4% ($n = 10$) five to eight. In 111 patients, all implants were lost. Of the 111 total loss patients the majority (77.5%, $n = 86$) were single implants (42.3%, $n = 47$) and two implants (35.1%, $n = 39$). About 76.8% ($n = 325$) of the lost implants were lost in the first year, 7.7% ($n = 32$) in the second, 15.1% ($n = 64$) in the consecutive 8 years up to the 10th year of follow-up. After 10 years, only two implant losses were registered. The cumulative implant-based survival

TABLE 1 Cumulative 1-, 3-, 5-, and 10-year implant and patient level survival rates (CiSR and CpSR) stratified by all investigated risk factors

Baseline data						
Parameter			**1 year**	**3 years**	**5 years**	**10 years**
Number of patients (*N*)			3717	2582	1699	674
Number of implants (*n*)			11 573	7768	5254	917
Average implants per patient			3.1	3.0	3.1	1.4
Age			58.6 ± 13.8	58.9 ± 13.3	58.5 ± 12.9	58.1 ± 11.1
Sex (M : F)			1:1.6	1:1.6	1:1.7	1:1.6
Parameter	Value		Cumulative Implant Survival Rates			
Sex	Male	CiSR	98.6	97.4	96.1	92.4
		CpSR	98.0	96.9	95.4	86.1
		n=	*n* = 4643	*n* = 3109	*n* = 2010	*n* = 388
		N=	*N* = 1454	*N* = 1001	*N* = 634	*N* = 261
	Female	CiSR	98.5	98.0	97.2	92.7
		CpSR	98.0	97.4	96.3	89.2
		n=	*n* = 6930	*n* = 4659	*n* = 3244	*n* = 529
		N=	*N* = 2263	*N* = 1581	*N* = 1065	*N* = 413
Age	Younger than 65 years	CiSR	98.6	97.9	97.1	92.2
		CpSR	98.0	97.3	96.4	88.9
		n=	*n* = 7019	*n* = 4851	*n* = 3457	*n* = 732
		N=	*N* = 2389	*N* = 1679	*N* = 1146	*N* = 512
	65 years and more	CiSR	98.5	97.6	96.3	94.1
		CpSR	98.0	97.1	95.1	88.4
		n=	*n* = 4554	*n* = 2917	*n* = 1797	*n* = 185
		N=	*N* = 1328	*N* = 903	*N* = 553	*N* = 162
Jaw	Maxilla	CiSR	98.6	97.7	96.7	93.1
		CpSR	98.2	97.3	96.1	89.5
		n=	*n* = 6591	*n* = 4540	*n* = 3141	*n* = 716
		N=	*N* = 1996	*N* = 1418	*N* = 958	*N* = 486
	Mandible	CiSR	98.5	97.9	97.0	91.6
		CpSR	98.4	97.6	96.7	89.1
		n=	*n* = 4982	*n* = 3228	*n* = 2113	*n* = 201
		N=	*N* = 1721	*N* = 1164	*N* = 741	*N* = 188
Region	High risk (lower 1st incisor and 2nd premolar)	CiSR	97.6	96.2	94.7	85.7
		CpSR	97.8	95.9	94.3	86.8
		n=	*n* = 809	*n* = 515	*n* = 342	*n* = 35
		N=	*N* = 256	*N* = 166	*N* = 112	*N* = 26
	Reference position (1st upper premolar, 1st lower molar) and all not significant regions	CiSR	98.4	97.6	96.6	92.3
		CpSR	98.0	97.2	95.9	88.4
		n=	*n* = 8165	*n* = 5458	*n* = 3652	*n* = 613
		N=	*N* = 2627	*N* = 1818	*N* = 1182	*N* = 450
	Low risk (upper canines and third molars, lower canines)	CiSR	99.3	98.9	98.2	95.2
		CpSR	99.2	98.7	97.8	94.0
		n=	*n* = 2599	*n* = 1794	*n* = 1261	*n* = 269
		N=	*N* = 834	*N* = 598	*N* = 405	*N* = 198
Loading	Immediate	CiSR	97.7	97.1	96.5	92.0
		CpSR	97.6	97.0	96.2	90.9
		n=	*n* = 2159	*n* = 1549	*n* = 1161	*n* = 344
		N=	*N* = 773	*N* = 586	*N* = 429	*N* = 280
	Delayed	CiSR	98.7	97.9	96.8	92.7
		CpSR	98.2	97.3	96.0	87.9
		n=	*n* = 9414	*n* = 6219	*n* = 4093	*n* = 573
		N=	*N* = 2944	*N* = 1996	*N* = 1270	*N* = 394
Smoker	No	CiSR	98.8	98.3	97.3	93.4
		CpSR	98.2	97.6	96.4	89.1
		n=	*n* = 9741	*n* = 6562	*n* = 4463	*n* = 811

(Continues)

TABLE 1 (Continued)

Baseline data						
Parameter			1 year	3 years	5 years	10 years
		N=	N = 3146	N = 2193	N = 1447	N = 626
	Yes	CiSR	97.4	95.1	93.9	88.3
		CpSR	97.3	95.0	93.1	80.3
		n=	n = 1832	n = 1206	n = 791	n = 106
		N=	N = 571	N = 389	N = 252	N = 48
Surgical technique	Punch	CiSR	98.5	97.7	96.7	92.7
		CpSR	98.0	97.1	95.8	87.9
		n=	n = 9967	n = 6671	n = 4440	n = 852
		N=	N = 3263	N = 2255	N = 1464	N = 614
	Flap	CiSR	99.4	99.4	98.5	92.0
		CpSR	98.9	98.9	98.0	90.5
		n=	n = 1606	n = 1097	n = 814	n = 65
		N=	N = 454	N = 327	N = 235	N = 60

For the risk factor "Region" for each jaw, implants were classified as significantly high-risk and low-risk regions compared to the most frequent (=reference) position, that is, first premolar in the maxilla and first molar in the mandible. "n" refers to the number of implants; "N" refers to the number of patients.

rates (CSRs) after 1, 3, 5, and 10 years were 98.5%, 97.8%, 96.8%, and 92.6%, respectively (for further details see Table 1). The cumulative patient-based survival rates after 1, 3, 5, and 10 years were 98.0%, 97.2%, 95.9%, and 88.0%.

The Kaplan–Meier cumulative implant and patient level survival rate (CSR) of all implants with a 95% confidence interval is shown in Figure 5. Details of the multivariate Cox PH model including patient as clustering term are summarized in Table 2.

3.2.1 | Gender and age

Eleven thousand, one hundred and fifty seven (58.9%) implants were placed in women and 7788 (41.1%) in men, respectively. With a P value of 0.464 gender was not shown to have significant influence on implant survival rates in the corresponding patient clustered Cox PH model. Nor the corresponding patient-level Cox model was significant (P = .269). The corresponding hazard ratio was 0.89 (95%-CI = 0.6-1.2) at implant level and 0.88 (95%-CI = 0.7-1.1) at patient-level. The overall statistics not considering time showed 2.2% implant losses in female and 2.3% in male patients. In total, 7398 implants were placed in patients aged 65 years or older and 11 547 implants in patients younger than 65, respectively. Also age was not a significant factor influencing implant survival rates with a hazard ratio of 0.93 (younger versus older, 95%-CI = 0.67-1.28, P = .645 in the Cox PH model) at implant level and 0.86 (95%-CI = 0.67-1.10, P = .211 in the Cox PH model) regarding older (≥65 years) versus younger (<65 years) patients. The overall statistics not considering time revealed 2.1% implants lost in older versus 2.3% in younger patients.

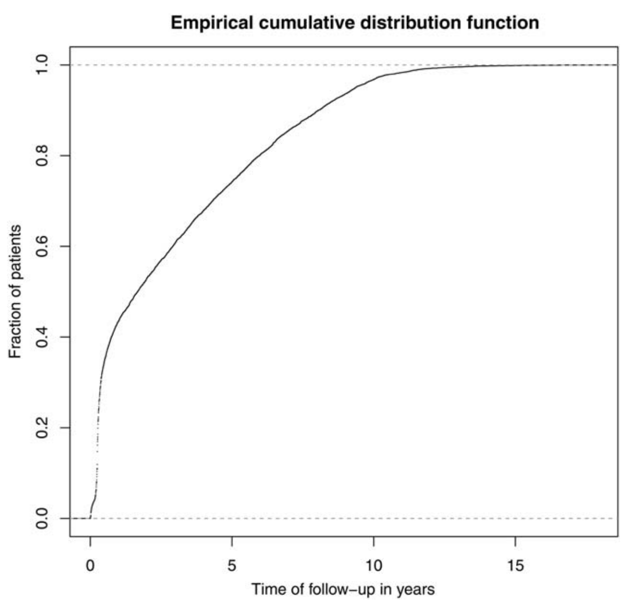

FIGURE 4 Empirical cumulative distribution function describing the fraction of patients with a maximum follow-up given in the x-axis. Inversely, the fraction of patients with a minimum follow-up can be read by subtracting the fraction of patients from 1.0

3.2.2 | Jaw and position

Ten thousand two hundred and fifty (54.1%) implants were placed in the maxilla and 8695 (45.9%) in the mandible, respectively. In the Cox PH model of the jaw, maxilla did not show significantly different loss rates compared to the mandible with a hazard ratio of 1.1

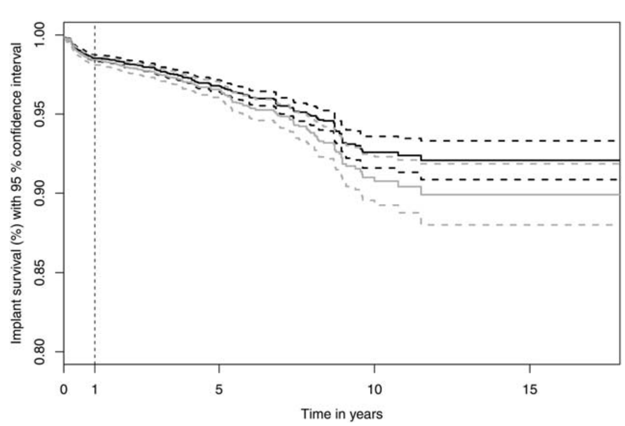

FIGURE 5 Kaplan–Meier cumulative survival rate (CSR) of all implants analyzed (black lines: implant-based, gray lines: patient-based) with 95% confidence interval

TABLE 2 Multivariate Cox proportional hazard model including patient as clustering term

Factor	Patient level HR	Patient level 95% CI	Patient level *P* value	Implant level HR	Implant level 95% CI	Implant level *P* value
Sex (female vs male)	0.9	0.7-1.2	0.487	0.9	0.7-1.3	0.654
Age above 65 years	1.4	0.1-1.9	**0.014**	1.3	1.0–1.8	0.068
Jaw (mandible vs maxilla)	1.0	0.7-1.3	0.767	1.1	0.8-1.4	0.705
Region (high: lower 1st incisor and 2nd premolar vs reference position)	1.6	1.1–2.1	**0.006**	1.7	1.2-2.3	**0.002**
Region (low: upper and lower canines, lower third molars vs reference position)	0.5	0.3-0.7	**<0.001**	0.5	0.3-0.7	**<0.001**
Loading (immediate vs delayed)	1.2	0.9-1.7	0.255	1.4	1.0–2.0	0.085
Smoker	2.1	1.5-2.9	**<0.001**	2.3	1.6-3.4	**<0.001**
Surgical technique (punch vs flap)	1.2	0.7-2.1	0.478	1.3	0.7-2.6	0.377
Concordance	0.639	se = 0.02		0.655	se = 0.016	
R^2 (max possible)	0.006 (0.360)			0.006 (0.344)		
Likelihood ratio test	58.44 on 8 df, $P < .001$			102.1 on 8 df, $P < .001$		
Wald test	52.24 on 8 df, $P < .001$			58.27 on 8 df, $P < .001$		
Score (logrank) test	60.43 on 8 df, $P < .001$			110.1 on 8 df, $P < .001$		
Robust	46.72, $P < .001$			44.52, $P < .001$		

The reference position was the 2nd premolar in the upper jaw and the 1st molar in the lower jaw. Significant *P* values in bold.

(95%-CI = 0.8-1.5, Cox PH model: $P = .429$) at implant-level and 1.1 (95%-CI = 0.9-1.4, Cox PH model: $P = .529$) at patient-level. The overall statistics not considering time showed 2.3% losses in the maxilla versus 2.1% in the mandible (for time related statistics see Table 2). In the maxilla, implants were most frequently placed in the first premolar region (21.5% of all maxillary implants, $n = 2208$). In reference to this position, canines (HR = 0.5, 95%-CI = 0.2-0.4, $P = .008$) and third molars (HR = 0.0, 95%-CI = 0.0-0.0, $P < .001$) showed significantly higher survival rates, while all other positions were statistically equivalent. In the mandible, the first molar was the most common site for implantation ($n = 2716$, 31.2% of all mandibular implants). In reference to this position, significantly higher rates of implant loss were found for central incisors (HR = 2.4, 95%-CI = 1.2–4.6, $P = .009$) and second premolars (HR = 1.7, 95%-CI = 1.2-2.5, $P = .007$) whereas the lower loss rate for canines was comparably weaker in significance (HR = 0.5, 95%-CI = 0.3-1.0, $P = .043$).

3.2.3 | Loading protocol

Three thousand eight hundred and twenty-seven implants (20.2%) were immediately loaded and did not show significantly higher implant failure rates (2.7%) when compared to delayed loading (2.1%). The corresponding hazard ratio was 1.3 (95%-CI = 0.9-1.8, Cox PH model: $P = .184$) at implant-level and 1.1 (95%-CI = 0.9-1.5, Cox PH model: $P = .348$) at patient-level. The remaining 15 118 implants (79.8%) were loaded after the second stage procedure or a transgingival healing time of approximately 3 months.

3.2.4 | Smoking

One thousand two hundred and thirty nine (15.9%) of all patients analyzed were smokers. The hazard ratio of smokers versus nonsmokers was 2.2 (95%-CI = 1.5-3.1, Cox PH model: $P < .001$) at implant level and 1.9 (95%-CI = 1.5-2.5, Cox PH model: $P < .001$) at patient-level. The overall statistics not considering time showed 3.9% losses in smokers versus 1.9% in nonsmokers.

3.2.5 | Flapless versus open surgery

The flapless technique (punch) was used in 92.5% of all cases analyzed (ie, 17 517 implants) opposed to 7.5% conventionally placed implants by use of flap techniques (ie, 1428 implants). The Cox PH did not show significant differences of the surgical techniques (implant-level: HR = 1.4, 95%-CI = 0.8-2.7, $P = .280$; patient-level: HR = 1.3, 95%-CI = 0.8-2.1, $P = .285$).

The multivariate Cox PH model proved significances of smokers and risky regions (see Table 2). The risky regions are compared to the most frequent placed position in each jaw (ie, 2nd premolar in the maxilla and 1st molar in the mandible) and identified to be the lower 1st incisor and 2nd premolar, while the canines in both jaws and the third molar in the lower jaw were less risky.

4 | DISCUSSION

Some decades ago when implantology started to become a valuable option for oral rehabilitation of partially and fully edentulous jaws, the main focus was primarily on osseointegration and its clinical correlate, that is, implant stability, as well as on implant survival rates. Over the years patients became more and more demanding with regard to esthetic expectations, and as advances in implant and prosthetic developments were made in parallel, nowadays patients can expect high success rates and predictable results with regard to both implant survival and esthetic aspects.

In view of this considerable progress, another aspect has more and more come into focus, that is, minimally invasive surgery where operating time is considerably shortened, postoperative swelling and scaring are greatly reduced, and no stitches are required. As a consequence, patient comfort can be significantly improved and patient satisfaction is usually higher when compared to conventional nonminimally invasive approaches.

The herein presented retrospective study refers to a large number of patients with 18 945 implants who were followed for up to 17.9 years. In the majority of cases ($n = 17\,517$, corresponding to 92.5% of all implants analyzed), implants were placed via a minimally invasive flapless approach.

With implant CSRs of 98.5%, 97.7%, 96.7%, and 93.0% after 1, 3, 5, and 10 years, respectively, and an overall survival rate of 97.3%, the flapless approach was shown to be successful and to reliably deliver predictable outcomes. In comparison, Jemt[5] reported 11-year CSRs of 98.5% and 97.2% for maxilla and mandible, respectively.

In this study, we observed an obvious drop in both implant- and patient-survival rate (CSR) that may, to some part, be a result of the number of observed patients between 5 and 10 years. A "steady-state level" of the survival curve after the first year does not seem to be established. If—as observed—a considerable number of patients drop out in the first year, and the implant failure changes the probability of a follow-up visit (ie, patient complaint), we observe negative selection bias. The Kaplan–Meier estimate was primarily designed to overcome the changing number of patients under risk over time not to underestimate the risk. Yet the Kaplan–Meier estimation does not compensate for the risk of the previously mentioned negative selection bias, which can lead to an overestimation if more of the few remaining problem patients than healthy patients come back. To illustrate, we simulated the Kaplan–Meier estimation hypothesizing that the initial drop out had not occurred and came to a 10 years cumulative implant survival rate of a hypothetical 95.9% instead of calculated 93.0%. This "drop out" effect may considerably impact especially long-term recall intervals, when number of patients under risk have dropped significantly and the number of patients coming to follow-up may contain a higher rate of patients with a loss than patients with no problems. In single tooth implant losses, this effect may be more pronounced when reporting implant level statistics. This was especially high, since drop out rates were even higher (1.9% observed of patients/implants observed after 10 years compared to the overall 5% of implants observed after 10 years), in comparison to nonsingle tooth implant losses. Thus, long-term survival data where many patients are lost to follow-up and only some few patients remain should be judged with caution.

Subgroup analyses of implant survival rates revealed some interesting results compared to available data in the international literature which are presented in the following paragraphs.

In concordance with other studies,[13–15] gender did not have significant influence on implant survival in our analysis. In contrast, lower CSR in men[16] and higher failure rates in women[17] were also reported in the international literature. In a systematic review and meta-analysis[18] including 91 publications, implant insertion in men was found to increase the risk of implant failure by 21% (risk ratio: 1.21).

Controversial reports can be found with regard to age which in one study[19] was identified as a significant factor influencing implant survival with lower CSR in older patients (>60 years). Similar to other authors,[16] we did not find significant differences in implant survival rates when comparing older ($\geq$ 65 years) versus younger patients. Recent scientific evidence was given by Jemt et al that younger edentulous patients with implant retained prosthesis appear to have a higher early loss rate and a higher mortality compared to elderly patients.[20]

Looking at the majority of published data[13,15,17,21–26] investigating into differences in implant survival rates of the upper versus lower jaw, more failures are commonly reported for implants placed in the maxilla than in the mandible. In contrast, Krebs et al[16] found higher success rates for implants placed in the maxilla. In a review of 71 studies with a minimum of 5 years follow up, higher long-term survival rates were described for maxillary moderately rough implants compared to minimally rough implants, whereas no such difference was found in the lower jaw.[27] In our analysis, no significant difference was seen between survival of implants placed in either jaw.

It can only be speculated why—in reference to the position of the lower first molar—implants placed in lower central incisor or second premolar position showed higher failure rates, whereas the outcome for implants in lower canine position was significantly better. Regarding the maxilla higher success rates were found for implants placed in canine and third molar position as compared to the position of the first premolar which was the predominant maxillary implantation site.

Referring to recent literature[28,29] immediate loading of implants shows high success rates, yet depending on the respective clinical situation (implant number and location, type of restoration). In a randomized clinical trial[30] evaluating both the clinical and radiographic outcome after immediate versus delayed loading of single-tooth implants, it was concluded that maxillary single implants could present satisfactory results after 1 year with either of these protocols. In a systematic review and meta-analysis[31] including 11 studies, the authors suggested that the differences in occlusal loading between immediate nonfunctional loading and immediate functional loading might not affect the survival of oral implants. In another meta-analysis[32] comparing delayed loaded submerged versus immediately loaded nonsubmerged implants, it was shown that for the latter technique failures are 1.78 times more likely to occur. In our study, no statistically significant difference was noted when comparing survival of immediate versus delayed loaded implants.

In a recent review and meta-analysis,[33] smoking was shown to negatively affect implant failure rates, infection risk (postoperatively) and marginal bone loss. In a retrospective study investigating 2670 patients with 10 096 implants,[34] smoking was identified as a statistically significant predictor for early dental implant failure. Although in our patient collective no detailed data were available regarding the number of cigarettes or pack years smoked, statistical analysis clearly demonstrated significantly higher rates of implant losses in smokers.

In a meta-analysis comparing conventional flapped to flapless implant surgery,[35] the latter technique was found to be associated with a significantly increased risk of implant failure in the test for overall effect. However, as a sensitivity analysis showed differences after pooling studies of high and low risk of bias separately, results must be interpreted cautiously. In our study, the high success rate of the flapless approach using the ATP-Punch was demonstrated by comparing this minimally invasive technique to the open surgery cases. The 5-year CSRs in flapless versus open surgery cases were 96.7% and 98.5%, respectively. The corresponding 10-year CSRs were 92.7% and 92.0%. Differences in implant survival were not statistically significant between punch and flap techniques.

A limitation of this study is that bone loss parameters were not included. Long-term success of implants may thus change in the future due to increased periodontal and peri-implant scientific evidence, which were not integral part of treatment at the beginning of the implantology era and therefore omitted in this 17-year retrospective study.

In conclusion, our data demonstrate the safety and medical efficacy of the ATP-Punch for flapless implant surgery. Implant survival rates were similar to the classic surgical flap approach and were influenced by implant position/site and smoking, but not by gender, age, implant location (upper vs lower jaw), loading protocols, or type of surgery.

CONFLICT OF INTEREST

P. Jesch, E. Bruckmoser, M. Krebs, T. Kladek, and R. Seemann do not have any commercial associations, current and within the past 5 years, that might pose a potential, perceived, or real conflict of interest. A potential conflict of interest is declared by W. Jesch since this author has a patent commercial association with DENTSPLY-Friadent, Mannheim, Germany.

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