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Maintenance Costs, Time, and Efforts Following Implant Therapy With Fixed Restorations Over an Observation Period of 10 Years: A Randomized Controlled Clinical Trial

Miha Pirc[1] | Naida Gadzo[1] | Marc Balmer[1] | Nadja Naenni[1] | Ronald E. Jung[1] | Daniel S. Thoma[1,2]

[1]Clinic of Reconstructive Dentistry, Center for Dental Medicine, University of Zurich, Zurich, Switzerland | [2]Department of Periodontology, Research Institute for Periodontal Regeneration, College of Dentistry, Yonsei University, Seoul, Korea

Correspondence: Daniel S. Thoma (daniel.thoma@zzm.uzh.ch)

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ABSTRACT

Objectives: To assess the costs and efforts of maintenance therapy following implant treatment with fixed restoration over an observation period of 10 years.

Material and Methods: This randomized controlled clinical trial included 64 patients who were randomly assigned to receive one of two implant systems (AST or STM) and fixed restoration. Patients were included in a regular maintenance program and were examined at loading, 1, 3, 5, 8, and 10 years. Outcome measures included technical and biological complications, time, efforts, and costs to resolve them.

Results: A total of 97 implants were placed in 64 patients (AST: 54, STM: 43). Patient recall rates at 5 and 10 years were 89% and 67%. In general, technical complications were resolved within one to two appointments (mean = 1.5), and biological complications required a mean of 1.3 appointments. The overall regular maintenance time for the period of 10 years amounted to 77 min per year. Technical complications occurred in 39.5% of the patients, with screw-loosening being the most common one (43.4% of all complications). The most time-consuming technical complication was abutment fracture (94 min ± 68), followed by screw fracture (84 min ± 38). The prevalence of peri-implant mucositis on the patient level was 30.2%, and it was 9.3% for peri-implantitis. The average annual maintenance costs amounted to 9% of the initial cost of the implant treatment over the period of 10 years.

Conclusions: Additional regular maintenance costs and costs due to the treatment of potential complications have to be taken into consideration when placing dental implants. The majority of technical complications could be resolved within one appointment, whereas the time needed to treat biological complications varied between one and three appointments for peri-implantitis.

1 | Introduction

Dental implants have become a cornerstone in modern dentistry for the restoration of missing teeth, offering a reliable solution with consistently high survival rates at both the implant and restoration level [1–5].

In the past, clinical studies focused on survival rates and basic success criteria, often overlooking the various complications that might occur in the long run. Systematic reviews at that time reported complication rates to range 4.4%–11.3% (biological), 5.1%–15% (technical), and 3.6%–13.6% (esthetic) [1, 2, 6]. While most complications are minor and can be

treated chairside, more severe issues, such as peri-implantitis (biological) or fractures of restorations (technical), may require additional chairside time, more appointments, and additional dental laboratory costs.

The importance of supportive periodontal treatment for the maintenance of periodontal health of the teeth is well documented [7–10]. Based on this knowledge, recommendations were made for patients having received dental implants to attend a dental hygiene session, as well as an examination by a dentist on a regular basis (at least once per year) [11]. Data on supportive care protocols and their regularity varies from 3 months to annual visits [11, 12]. However, it has been demonstrated that peri-implant health can be maintained through implant maintenance therapy [12, 13].

Dental implant therapy, being predominantly an elective therapeutic treatment option, is associated with relatively high costs. Given that supportive maintenance care is strongly recommended, patients should be informed beforehand about the additional regular costs associated with the therapy. Apart from that, costs are increasing due to the treatment of potential complications (ranging up to 15% for single crowns during a 5-year follow-up) [2]. Although complication rates are well documented in the literature with a plethora of systematic reviews [1, 5, 14, 15], a limited number of studies addressed the maintenance costs of implant therapy. The existing studies are limited by their focus on highly selected patient cohorts and reliance on estimated costs, which may not accurately reflect the actual costs encountered in daily clinical practice [16, 17].

The aim of the present study was, therefore, to assess the costs and efforts of maintenance therapy following implant treatment with fixed restorations over an observation period of 10 years.

2 | Materials and Methods

The present study was designed as a randomized controlled clinical trial at the Clinic for Reconstructive Dentistry, University of Zurich, Switzerland. It was approved by the local ethical committee (Kantonale Ethikkommission Kanton Zürich, Ref. Nr. KEK-ZH-Nr. 2013-0121) and conducted according to the principles outlined in the World's Medical Association's Declaration of Helsinki on experimentation involving human subjects ("World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects," 2013). All patients signed an informed consent prior to inclusion in the study. The specific study design, surgical protocol, and inclusion and exclusion criteria have been reported previously [18].

Specifically, the following inclusion criteria were applied:

- Patients had to be healthy and of legal age (> 18 years old).
- No local jaw pathology.
- No active periodontal disease (periodontal probing depths < 4 mm).
- Good oral hygiene (full mouth plaque control record < 25%) [19].
- Adequate control of inflammation (full mouth bleeding on probing < 25%) [20].
- Implant therapy planned with fixed implant-borne restorations.

In brief, 64 patients in need of implant therapy were consecutively enrolled. Patients were randomly allocated to receive implants from one of two systems: AST (Astra Tech Osseospeed; Dentsply Sirona Implants) or STM (Straumann Bone Level Implants, SLAactive; Straumann AG) using a computer-generated randomization list.

All surgical procedures were performed according to the standard protocols of the respective implant systems and based on the manufacturers' recommendations. Generally, implants were placed with the implant shoulder at the level of the bone crest. Some of the implants were placed with an increased sink depth due to prosthetic reasons. In case of a fenestration or dehiscence a guided bone regeneration (GBR) procedure was performed, using xenogeneic or synthetic bone substitute materials and a collagen membrane.

The prosthetic procedures were made according to the guidelines of the individual implant systems. Screw-retained or cemented restorations were used based on the clinical situation and the clinician's preference. The day of the insertion of the final prosthesis was considered as baseline. Types of restorations are presented in Table 1.

Patients were then included in a regular maintenance program according to their individual needs. More thorough clinical follow-up examinations were performed at 1, 3, 5, 8, and 10 years and included standardized intraoral periapical radiograph, probing depth (PD), plaque control record (PCR) [19] and bleeding on probing (BOP), measured at six sites for all implants and the two neighboring teeth (these outcomes for different follow-up years are reported in separate publications) [18, 21–23]. During these appointments, the examiner or dental hygienist made decisions regarding the need for further visits based on the yearly examination. In total, 91% of all patients (39 patients) had a regular dental hygiene appointment once per year, and

TABLE 1 | Type of reconstruction at the implant and patient levels.

	Implant level		Patient level	
	AST	STM	AST	STM
ISSC	29	13	19	12
ISSC splinted	4	2	2	0
FDPs	13	15	6	8
ICFDPs	8	13	6	11
Total	54	43	33	31

Abbreviations: AST, Astra; FDPs, fixed dental prostheses; ICFDPs, implant-supported cantilever fixed dental prostheses; ISSC splinted, splinted implant-supported single crowns; ISSC, implant-supported single crown; STM, Straumann.

9% (4 patients) had it twice per year. The examiner was not involved in the surgical or prosthetic treatment. Throughout the 10-year observation period, four trained and calibrated examiners conducted clinical assessments on the study's included patients. Calibration of the examiners for clinical assessments and measurements was performed by the principal investigator, ensuring consistency. The clinical measurements were rounded to the nearest 0.5 mm.

2.1 | Outcome Measures

2.1.1 | Time, Efforts, and Costs to Treat Biological and Technical Complications

All biological and technical complications were treated, and time, efforts, and costs were calculated. This included the time reserved for the appointment to treat the complication, the need for the involvement of a dental laboratory, and the actual treatment costs of the complication. In addition, maintenance costs were calculated based on the number of appointments. This included dental hygiene sessions (according to individual needs) with a yearly control visit by a dentist and extra appointments for the follow-up examinations (at baseline, 1, 3, 5, 8, and 10 years) performed by a specialist. Costs were assessed based on Switzerland's official taxation rates. Moreover, actual treatment expenses were calculated as proportions of the initial treatment costs to enable international comparisons. All patients received in-house treatment, and only appointments related to the study site were considered when assessing time, costs, and efforts. During each appointment, the examiner verbally confirmed whether any additional appointments (e.g., replacement of fillings, endodontic treatments, etc.) were scheduled elsewhere.

2.1.2 | Biological Complications

As a biological complication, peri-implant mucositis and peri-implantitis were assessed according to the consensus report of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. The incidence of biological complications was assessed at the follow-up visits or in case patients came in for an extra visit.

Peri-implant health was defined as the absence of erythema, bleeding on probing, swelling, and suppuration. Biological complications included:

- *peri-implant mucositis* (BOP+) and
- *peri-implantitis* (BOP+, progressive marginal bone loss between 1 year and 10 years) according to the 2017 World Workshop on the classification of periodontal and peri-implant diseases and conditions [24, 25]

2.1.3 | Technical Complications

All technical complications, including implant fractures, abutment fractures, fractures of the veneering ceramic (whether minor or major), loosening of the abutment screw, and abutment screw fractures, were meticulously documented in the patient records and during follow-up examinations. If a complication was reported by a patient and resulted in an additional appointment, it was also recorded in the patient file. At each follow-up visit, restorations were assessed for chipping and fractures based on clinical examination, and the stability of the implant crowns was manually evaluated using dental instruments.

2.1.4 | Survival Rates

Survival rates of implants and restorations as well as technical and biological complications were calculated on the implant and patient level. Implant survival was defined as the implant being in place and stable. Survival of the restoration was defined as the restoration being in situ.

2.2 | Statistical Analyses

A software program (Excel, Microsoft Corporation, Redmond, Washington, USA) was used to process the data. For the metric variables, mean, standard deviations, median, and quartiles were calculated. Due to the exploratory nature of this study, descriptive statistics were used at the implant level as well as at the patient level using a software program (Excel, Microsoft Corporation, Redmond, Washington, USA).

The authors completed the CONSORT checklist in accordance with the appropriate guidelines/checklist.

3 | Results

A total of 64 patients were included in this study: 33 patients in group AST (17 females and 16 males) and 31 in group STM (21 females and 10 males). The mean age at baseline for group AST was 55.0 (SD ± 11.6) years and 54.3 (SD ± 16.1) years for group STM. In total 97 implants were placed, 68 in the upper jaw and 29 in the lower jaw. Patients received 54 implants in group AST and 43 implants in group STM. All implants were placed between February and December 2009.

The mean time between implant placement and the insertion of the final prosthesis was 9.14 months (SD ± 4.47, range: min. 2.46 to max. 21.62 months) for group AST and 10.52 months (SD ± 4.61, range: min. 3.75 to max. 20.96 months). An overview of the type of restoration is given in Table 1.

A total of 43 patients (AST: 23 patients; STM: 20 patients) with 69 implants (AST: 37 implants; STM: 32 implants) attended the follow-up appointment at 10 years (mean observation period 10.4 years) with a mean age of 67.3 years (SD ± 11.0). Survival rates on the implant level amounted to 95.7% (AST: 97.3%; STM: 93.8%). The drop-out rate amounted to 31.25%. Loss of follow-up occurred due to reasons including relocation, diminished mobility due to age or health conditions, and passing away.

3.1 | Number of Visits

3.1.1 | Patients Free of Complications

Patients without technical or biological complications required on average one visit per year for a dental hygiene session. This appointment was combined with a more thorough examination by a dentist at 1, 3, 5, 8, and 10 years. Since the visit with the dental hygienist and the dental examination took place on the same day, these two were considered as one appointment.

Over the observation period of 10 years, patients therefore were scheduled for one regular appointment per year.

At the implant level, 45 implants remained free of *technical* complications (AST: 19; STM: 26), while at the patient level, 26 patients were without technical complications (AST: 10; STM: 16). Regarding *biological* complications, 44 implants remained free of complications at the implant level (AST: 28; STM: 21), with a corresponding total of 26 patients unaffected by biological complications (AST: 16; STM: 10).

3.1.2 | Patients With Technical and/or Biological Complications

In general, technical complications were resolved within one to two appointments (mean = 1.5; SD = 2.56). In two patients with screw-loosening and one patient with a screw fracture, two appointments were necessary. In one patient, the occurrence of a minor chipping required five visits. The treatment involved a dental laboratory and eventually the replacement of the crown. In one of the patients, an abutment fracture required four visits and the involvement of a dental laboratory and a replacement of the crown.

The treatment of biological complications required a mean of 1.3 (SD ± 0.88) appointments. The treatment of peri-implant mucositis resulted in a mean of 1.56 (SD ± 0.98). The respective therapy of peri-implantitis resulted in a mean of 2.4 (SD ± 0.79) appointments. In addition, three implants were removed due to peri-implantitis (one implant in group AST and two in group STM).

Overall, patients had to attend an additional 1.3 appointments due to technical and/or biological complications during the observation period of 10 years.

3.2 | Maintenance Time

The regular maintenance time scheduled for a dental hygiene session was 60 min. An additional, more thorough clinical examination (at 1 year and then every second year) was scheduled for 30 min. The overall regular maintenance time for the period of 10 years amounted to 77 min per year.

The mean time needed for the treatment of each technical complication is reported in Table 2. In general, the most time-consuming complication was abutment fracture, which resulted in 94 min (SD ± 67.5), followed by screw fracture, which resulted in 84 min (SD ± 37.7). The least time-consuming minor chipping with 41 min (SD ± 12.1).

TABLE 2 | Mean time and costs needed for resolving different types of technical complications.

Type of complication	Minor chipping ($n = 15$)	Major chipping ($n = 3$)	Screw fracture ($n = 5$)	Screw loosening ($n = 23$)	Abutment fracture ($n = 3$)	Implant crown replaced ($n = 3$)	Composite removal ($n = 1$)
Mean time (min)	41 (±12)	65 (±9)	84 (±38)	43 (±14)	94 (±68)	60 (±52)	30
Average cost (CHF)	100	159	205	105	1229	1146	73
Percentage of the initial cost	2%	4%	5%	2%	27%	26%	2%

Note: n: number of complications.

3.3 | Maintenance Costs

Patients attended one dental hygiene session per year. This appointment with the dental hygienist was combined with a short examination by a dentist. This resulted in annual maintenance costs of 223 CHF.

The costs of the more thorough follow-up clinical examinations performed at 1, 3, 5, 8, and 10 years amounted to 1300 CHF (260 CHF per visit).

Therefore, the overall mean costs for the period of 10 years amounted to 363 CHF per year and per patient.

3.4 | Technical Complications

The type and count of technical complications on the implant level are summarized in Table 3.

Technical complications occurred in 34.8% of the implants and 39.5% of the patients (AST: 48.6% of the implants, 56.5% of the patients; 18 implants, 13 patients and STM: 18.8% of the implants, 20% of the patients; 6 implants, 4 patients). At the implant level, 45 implants remained complication-free (AST: 19; STM: 26). On the patient level 26 patients were without complications (AST: 10; STM: 16). The majority of complications occurred during the first 3 years of observation (60.4%; 32 complications). Between the third and fifth year 20.7% (11 complications) were noted, between 5- and 8-year follow-ups 11.3% (6 complications), and between the 8- and 10-year follow-ups 3.8% (2 complications).

The most common complication (43.4% of all complications) was screw-loosening. The majority of screw-loosening events occurred within the first 3 years after the delivery of the final prosthetic restoration (71.4%), all of which were noted in group AST. The second most common complication was a minor chipping (18.9%) (Figure 1), followed by a screw fracture (9.4%) and a major chipping and abutment fracture (5.7%). The dental laboratory was involved in six patients due to minor or major chipping or abutment fractures.

TABLE 3 | Technical complications count on implant level.

	AST	STM	Total
Minor chipping	10	5	15
Major chipping	2	1	3
Screw loosening	23		23
Screw fracture	5		5
Abutment fracture	3		3
Implant crown removed	3		3
Composite lost		1	1
Total	46	7	53

Note: The number of affected implants/patients in each group—AST: 18 implants, 13 patients; STM: 6 implants, 4 patients.
Abbreviations: AST, Astra; STM, Straumann.

3.5 | Biological Complications

The number of biological complications for each implant group is presented in Table 4.

The prevalence of biological complications was 34.8% on the implant level and 39.5% on the patient level (30.4% in group AST and 50% in group STM).

The prevalence of peri-implant mucositis amounted to 26.1% on the implant level (21.6% in group AST and 31.3% in group STM). On the patient level, the respective prevalence was 30.2% (26.1% in group AST and 35% in group STM). The prevalence of peri-implantitis (Figure 2) was 8.7% on implant level (2.7% in group AST and 9.4% in group STM) and 9.3% (4.3% in group AST and 15% in group STM) on the patient level.

At the implant level, 44 implants remained complication-free (AST: 28; STM: 21), and at the patient level, 26 patients (AST: 16; STM: 10).

3.6 | Overall Maintenance Costs of Implant Therapy Over 10 Years

The average maintenance costs to treat the various *technical complications* amounted to 205 CHF (patient level) during the observation period of 10 years (Table 2). The most expensive and time-consuming technical complication was abutment fracture (1229 CHF, 27% of the initial treatment costs) followed by replacement of the crown (1146 CHF, 26% of the initial treatment costs). The initial treatment cost amounted to 4500 CHF.

The average maintenance costs to treat *biological complications* amounted to 212 CHF during the observation period of 10 years (patient level), which resulted in 5% of the initial treatment costs. The treatment of peri-implant mucositis on average amounted to 567 CHF (13% of the initial treatment costs),

FIGURE 1 | An example of a technical complication, in this case, a minor chipping, which was resolved with polishing only and did not include additional dental laboratory work.

TABLE 4 | The count of *biological complications* for each group on the *implant level*.

	AST	STM	Total
Peri-implant mucositis	8	10	18
Periimplantitis	1	5	6
Total	9	11	24

Note: Implants removed per each group (AST: 1, STM: 2), number of affected patients per group (AST: 7 patients, STM: 10 patients).
Abbreviations: AST, Astra; STM, Straumann.

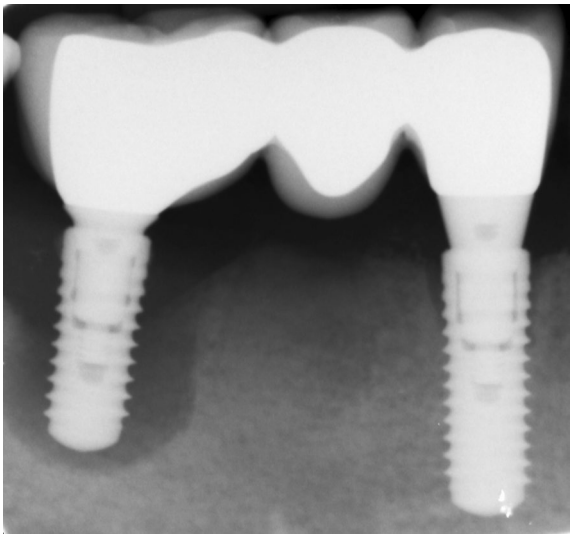

FIGURE 2 | An example of a biological complication, in this case, a peri-implantitis case, where an implant had to be removed.

peri-implantitis 871 CHF (19% of the initial treatment costs), and removal of the implant an additional 543 CHF (12% of the initial treatment costs).

The *overall costs* per patient including regular maintenance and treatment of technical and/or biological complications over the observation period of 10 years amounted to 404 CHF per year (9% of the initial treatment costs).

4 | Discussion

The present RCT conducted over a 10-year observation period examined the costs and efforts associated with maintenance care following implant therapy. Regular maintenance care was on average performed once per year. In addition, the handling of technical and biological complications resulted in a 13% increase in appointments per year. Patients attended an average of 1.3 appointments per year for regular maintenance and to address technical and biological complications. In addition to the time needed to resolve complications, there were additional costs involved, which amounted to an annual average of 9% of the initial treatment cost.

Dental implant therapy has become a widely accepted treatment option for patients who are partially or completely edentulous. Although it is known to be associated with high costs during the active treatment phase, there is limited scientific literature available on the actual maintenance care required and the efforts needed to resolve complications. The current study found that patients experienced a 13% increase in the number of appointments due to various complications in addition to their regular maintenance care appointments. While this resulted in additional costs and time for the patients, it is difficult to compare with existing literature since most studies only consider the absolute cost of maintenance or restrict their comparisons to tooth- and implant-supported restorations [17, 26–29].

The absolute yearly costs for regular maintenance care and resolving different complications amounted to 404 CHF, which is substantially higher than the total costs reported in a recent publication [17]. In their study, the authors assessed the total costs of complications that occurred over an observation period of 8.5 years and reported costs ranging from 878 to 1210 €, which is substantially lower than the costs observed in the current study. However, it is important to put absolute numbers into perspective by considering the cost of the initial treatment. In this study, the average cost of complications amounted to 9% of the initial cost, compared to 11.1% reported in a study by the Swedish group. It is noteworthy that the authors of this study included more extensive treatments, which are inherently associated with a higher risk of complications [6]. These findings highlight the importance of reporting time-based fiscal accounting and actual chair time when reporting complications, as previously suggested [30]. Doing so would increase the accuracy of cost reporting and facilitate comparisons across different regions.

It has been reported in several publications that regular maintenance visits are the most effective and cost-efficient method for ensuring long-term implant health. However, it should be noted that regular maintenance visits are not only important for peri-implant health but also for maintaining healthy "normal" dentition. In this study, the reported costs and efforts were divided into the cost of actual complications and regular maintenance, which would be required regardless of whether implants were placed. When taking this into account, the actual costs of resolving complications amounted to 5% of the initial cost (205 CHF) for technical complications and 5% (212 CHF) for biological complications.

In this article, the term "technical complications" refers to both mechanical issues affecting prefabricated parts (such as implants, abutments, and screws), as well as complications relevant to laboratory-fabricated parts (such as chippings and crown fracture) [3].

Overall, technical complications accounted for 39.4% of patients in group AST and 14% in group STM. While this may seem high, it is worth noting that the majority of these complications were related to mechanical complications, such as screw-loosening, which can be resolved relatively quickly. The majority of complications occurred within the first few years after the insertion of final restorations, which is consistent with systematic reviews reporting similar rates of technical complications. Importantly, the majority of these complications occurred in only one of the groups, which could be explained by the previous connection

system used that has since been changed. This underscores the importance of informing patients about potential complications and clearly explaining what is covered under the guarantee and what is not.

The reported prevalence of biological complications in the literature ranges between 13% and 47% [24, 31, 32]. This is similar to the occurrence of biological complications in the current study, where they occurred in 30.4% in group AST and 50% in group STM. Despite regular and individualized maintenance visits, clinicians still need to take this into account. Management of these complications results in additional costs and efforts, which in the current study ranged from 4.7% to 19.4% of the initial implant cost. With the severity of the biological complications also the expenses increased. Moreover, biological complications often result in implant removal.

It should be noted that the treatment protocol in this study was not entirely standardized, as the only requirement for the restorations was that they be fixed. While this might be viewed as a limitation, it was deliberately designed to mirror the conditions of a typical private practice setting. However, the broad inclusion criteria, which covered various factors such as implant location (maxilla, mandible, anterior, posterior), the use of guided bone regeneration (GBR), type of healing (submerged, transmucosal), loading time, retention type, and restoration material, may also be considered a potential drawback. Based on the results and the current trend toward individualized medicine and dentistry, it is important to emphasize that patient-related factors and individual risk assessments should be carefully considered before implant placement to minimize potential complications as much as possible. Since the study was conducted at a university, participants received regular individualized examinations based on their recall schedules. During each appointment, the examiner verbally confirmed whether any additional appointments were scheduled elsewhere (e.g., replacement of fillings, endodontic treatments, etc.). These non-study-specific appointments were not noted, as they were deemed irrelevant to the study outcomes. This approach is similar to a well-organized private practice, and therefore, the results can be generalized to real-world situations.

5 | Conclusions

Patients being treated with dental implants supporting fixed restorations need to be informed about the additional efforts required, including time, appointments, and costs, beyond regular maintenance. Technical and biological complications were observed at a rate of 35% over a 10-year observation period. This in turn resulted in an increase in appointments (+13% compared to the regular maintenance interval) and costs (+5% for the handling of complications).

Author Contributions

M.P. analyzed the data, major contribution to finishing the manuscript. N.G. performed the follow-ups. M.B. contributed to finishing the study. N.N. contributed to finishing the manuscript. R.E.J. conceived the ideas, supervision, and contribution to finishing the manuscript. D.S.T. conceived the ideas, supervision, and major contribution to finishing the manuscript.

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Ethics Statement

The study was approved by the local ethics committee (Kantonale Ethikkommission Kanton Zürich, Ref. Nr. KEK-ZH-Nr. 2013-0121) and was performed following the principles outlined in the World's Medical Association's Declaration of Helsinki on experimentation involving human subjects.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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