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Clinical outcomes of small-diameter implant-retained overdentures: a retrospective analysis

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KEYWORDS Survival rate, Clinical outcome, Small-diameter implant, Small-diameter implant-retained overdenture.

ABSTRACT

Aims To analyze the survival rate of small-diameter implant (SDI) retained overdenture and evaluate the implant and attachment complications, as well as prosthetic maintenances, over a follow-up period of ≤4.5 years.

Materials and methods Implant placement procedures were performed by dentists at the Advanced General Dentistry Clinic, Faculty of Dentistry, Mahidol University (Thailand) for all patients treated since 2016. Panoramic and periapical radiographs were taken before and after implant placement, to assess bone height around the implant. SDIs of 3 mm diameter and 10 mm length (PW plus®, PWSE, Nakhon Pathom, Thailand) were placed. After implantation for at least 2 months, corresponding housings were incorporated into overdentures using a conventional loading protocol. Assessment of implant survival rate, implant complications, and prosthetic maintenances were conducted as part of a regular implant checkup during the recall period from 2019–2020. Subsequently, patient characteristics, implant survival rate and complications, attachment complications, and prosthetic maintenance procedures were analyzed using descriptive statistics.

Results Patients included in the study (n = 27) had a mean age of 68 years, and received 119 SDIs (41 in maxilla, 78 in mandible) and 38 overdentures (15 complete overdentures, 23 removable partial overdentures). The implant survival rate was 98.3% at mean survival time of 19.4 months (range, 6–55 months). After overdenture delivery, complications related to implant, attachments, and prosthetic maintenances were recorded. One implant complication (peri-implantitis) was recorded among 119 SDIs (0.8%). Attachment (Equator®) complications included: deformation of attachment matrices (34.4%), loss of attachment screw preload (14.0%), wear of metal housing (1.6%), wear of attachment head (0.8%), and dislodgement of attachment screw (0.8%). Prosthetic maintenance procedures comprised occlusal adjustment (72.7%), tissue surface adjustment (6.8%), denture base repair (6.8%), addition of artificial teeth (2.3%), and repair of artificial teeth (2.3%).

Conclusion Our findings suggest that SDI retained overdenture is a successful treatment modality with a high implant survival rate (98.3%) over a 4.5 year follow-up period. Nevertheless, SDI retained overdenture maintenance is crucial.

INTRODUCTION

Implant-retained overdenture has become a treatment option for edentulous patients because of its simplicity, cost-effectiveness, and high success rate. Patients who receive this type of treatment can achieve higher quality of life, due to the improved retention and stability of the prosthesis, along with superior comfort and function (1, 2).

Standard implant-retained overdenture has good long-term results; however, it has some disadvantages, including high cost and technical difficulty when the bone volume area is inadequate, which potentially necessitates bone grafting procedures. Moreover, some chronic systemic diseases can negatively affect the procedure (3, 4).

Mini dental implants (MDIs) are dental implants fabricated using the same biocompatible materials as regular dental implants, with smaller diameter (< 3 mm) (5, 6). Most reports in the literature are of implants with diameter of 1.8 to 2.9 mm (5). Implants of diameter 3 to 3.5 mm are commonly reported as narrow/small diameter (6), and the terminology used for reduced diameter implants in the literature varies: the terms mini dental implants (MDI), narrow diameter implants (NDI), and small diameter implants (SDI) have been used interchangeably in the past (5). In this study, SDI refers to dental implants with diameter of 3–3.5 mm. MDI and SDI are the optimal modalities for placement in areas with narrow or atrophic bone, owing to their smaller size. In such cases, the surgical technique used for MDI placement is flapless, without bone grafts, and results in fewer complications than standard implant placement. Multiple implants can be placed to stabilize both complete or partial removable prostheses and are offered at a lower cost, making them more accessible for patients with limited financial resources (3, 5, 7-9). MDI and SDI-retained overdentures can successfully improve patient chewing and speaking ability, quality of life, and satisfaction. Furthermore, MDI and SDI are

established as successful and safe options to support removable prostheses (10, 11).
Although the demand for SDI has grown, very few investigations have examined the long-term implant survival rate and clinical outcomes following the use of SDI to retain overdentures. Given this dearth of evidence, in this study we aimed to analyze the survival rate of SDI-retained overdenture, implant complications, attachment complications, and prosthetic maintenance procedures over a follow-up period of ≤ 4.5 years.

MATERIALS AND METHODS

Study design

Included patients were treated with SDI-retained overdentures by dentists at the Advanced General Dentistry Clinic, Faculty of Dentistry, Mahidol University (Thailand), since 2016. Implant placement was conducted using standard procedures. Panoramic and periapical radiographs were used to assess bone height before implant placement and for evaluation after the procedure. SDIs of 3 mm diameter and 10 mm length (PW plus®, PWSE, Nakhon Pathom, Thailand) were placed. A pilot drill was used to prepare the implantation site, as recommended by the manufacturer. Primary stability was examined using a torque wrench. After implantation for at least 2 months, Equator® abutments (resilient attachments) were set up and the corresponding housing incorporated into the overdentures using self-curing acrylic resin with a conventional loading protocol.
Patients were recalled by the researcher during 2019 to 2020 to assess implant survival, implant complications, attachment complications, and prosthetic maintenance. Patients were assessed during a single visit, as for a regular implant checkup. Patient age, gender, medical status, date of implantation, site of implantation, SDI number, and type of prosthesis were recorded on clinical examination and patient records.

Subject selection

The study inclusion criteria were: patients treated with SDI to retain overdenture, without clear contraindications prior to implantation procedure. Exclusion criteria were: patients undergoing active treatment for malignancy; patients with uncontrolled psychiatric disorders; intravenous bisphosphonate prescription; recent myocardial infarction, cerebrovascular accident, or valvular prosthesis surgery; and immunosuppression (12). Clinical examinations of patients included assessment of signs and symptoms, implant mobility, probing depth and exudation, presence of implant, periapical radiographic evaluation, prosthetic complications, maintenance sessions, and aftercare needs. The study protocol was approved by the Ethics Committee of the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board (Certificate no. COA.No.MU-DT/PY-IRB 2019/028.1305).
Implant survival criteria, according to The International Congress of Oral Implantologists (ICOI), Pisa Consensus Conference 2007 (13), are shown in Table 1. Implant survival was defined as the implant remaining functional, and not meeting any of the following failure criteria: pain on function, mobility, uncontrolled exudate, no longer present in the mouth, and radiographic bone loss more than half of implant length (Table 1).

Statistical analysis

Statistical analysis was performed using SPSS statistics version 18. Patient characteristics, implant and overdenture characteristics, implant complications, attachment complications, and prosthetic maintenance were evaluated by descriptive statistical analysis. SDI survival rate was evaluated by Kaplan–Meier statistical analysis.

RESULTS

Patient characteristics

Twenty-seven patients with mean age 68 years (range, 54–92 years) were treated with SDI-retained overdentures since 2016; 51.9% of patients were female. Medical histories included hypertension (32.6%), dyslipidemia (17.4%), diabetes mellitus (19.6%), history of stroke (6.5%), history of cancer (4.3%), and other diseases (19.6%), such as osteoporosis, hepatitis B, Alzheimer,

Implant Quality Scale Group	Clinical Conditions
I. Success (optimum health)	a) No pain or tenderness on function b) No mobility c) < 2 mm radiographic bone loss from initial surgery d) No history of exudates
II. Satisfactory survival	a) No pain on function b) No mobility c) 2–4 mm radiographic bone loss d) No history of exudates
III. Compromised survival	a) May have sensitivity on function b) No mobility c) Radiographic bone loss > 4 mm (less than 1/2 of implant body) d) Probing depth > 7 mm e) May have history of exudates
IV. Failure (clinical or absolute failure)	Any of the following a) Pain on function b) Mobility c) Radiographic bone loss > 1/2 implant length d) Uncontrolled exudate e) No longer in mouth

TABLE 1 Health Scales for Dental Implants issued by The International Congress of Oral Implantologists (ICOI), Pisa Consensus Conference 2007.

Implant placement area	Location: Number (%)		
	Anterior region	Posterior region	Total
Upper arch	8 (6.7)	33 (27.7)	41 (34.4)
Lower arch	24 (20.2)	54 (45.4)	78 (65.6)
Total	32 (26.9)	87 (73.1)	119 (100)

TABLE 2 Implant placement area (119 SDIs).

Type of overdenture	Location: Number (%)		
	Upper arch	Lower arch	Total
Complete overdenture	4 (10.5)	11 (28.9)	15 (39.4)
Removable partial overdenture (Kennedy class I, II)	9 (23.7)	11 (28.9)	20 (52.6)
Removable partial overdenture (Kennedy class III)	2 (5.3)	1 (2.7)	3 (8.0)
Total	15 (39.5)	23 (60.5)	38 (100.0)

TABLE 3 Type of overdenture (n = 38).

and Parkinson's disease. Thirty-eight overdentures were retained by 119 SDIs. Data on implant placement area and types of overdentures are presented in Tables 2 and 3.

Implant survival

The time periods from date of implantation to date of implant loss and date of last checkup were analyzed using Kaplan-Meier curves. Overall, the implant survival rate was 98.3% at mean survival time 19.4 months (range 6 to 55 months) (Fig. 1). After prosthesis loading, no implants failed.

Among 119 SDIs, two were lost before prosthetic loading, due to peri-implantitis in the first and third months after implantation. The first failed implant was located at the upper left canine, and retained an upper free-end-saddle removable partial overdenture. Clinical examination found soft tissue swelling, bone loss to half of the fixture, and implant mobility. A large amount of buccal bone resorption was also found prior to implantation. The second failed implant was located at the lower right first molar and retained a lower free-end-saddle removable partial overdenture. Clinical examination showed implant mobility. The patient informed the dentist that he mainly used the right side of his mouth, due to a history of left buccal tumor surgery. Both patients had type 2 diabetes mellitus, a history of chronic periodontitis, and keratinized gingiva < 2 mm.

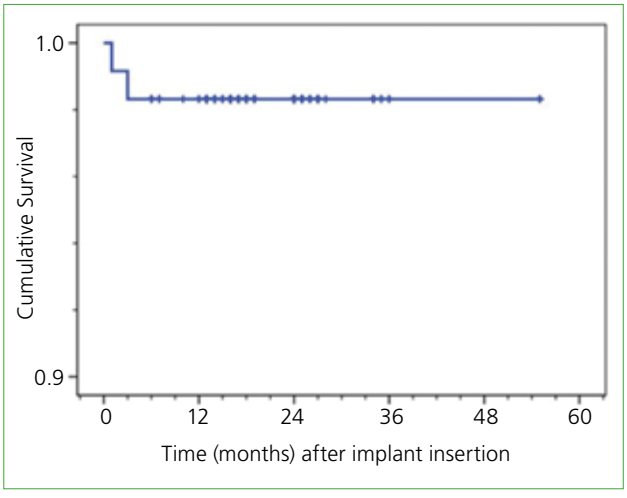

FIG. 1 Kaplan-Meier curve for implant survival.

Implant complications

One of 119 SDIs (0.8%) resulted in peri-implantitis with pus exudation, probing depth of 5 mm, and 2 mm bone loss in the second month after overdenture delivery (the eighth month after implantation). The implant retained an upper removable partial overdenture (free-end saddle). Traumatic occlusion at the implant site was detected during function. Mechanical debridement, antiseptic cleaning, and occlusal adjustment were conducted. The implant survived until it was rechecked, with no exudation; patient signs and symptoms and implant condition were stable.

Attachment complications

Types of attachment complications recorded are shown in Table 4. Attachment complications were observed from 3 to 45 months from the date of overdenture delivery to the date of follow-up. Deformation of Equator® matrices occurred frequently (34.4%) and wear of metal housing occurred in 2 SDIs (1.6%) (Fig. 2). The first SDI with metal housing wear retained a complete overdenture and the other a lower free-end-saddle removable partial overdenture. Both patients with metal housing wear had

Attachment complication	Implant (%)
No complication	59 (48.4)
Deformation of Equator® matrices	42 (34.4)
Loss of Equator® screw preload	17 (14.0)
Wear of metal housing	2 (1.6)
Wear of Equator® head	1 (0.8)
Dislodgement of Equator® screw	1 (0.8)
Total	122 (100)

**From 119 SDIs, 3 implants had more than one attachment complication.*

TABLE 4 Types of attachment complication (119 SDIs) .

FIG. 2 Deformation of nylon matrices (A),(B).
Wear of metal housing (C).

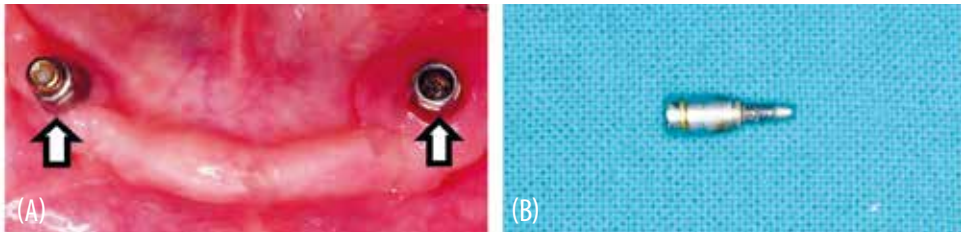

FIG. 3 Wear of Equator® head and dislodgement of the Equator® screw (A). Dislodgement of the Equator® screw (B).

history of chewing hard food, which may have been the primary cause of the problem. Wear of the Equator® head (0.8%) and dislodgement of the Equator® screw (0.8%) occurred in the same patient 45 months after delivery of a two-implant-retained lower complete overdenture. The presenting wear of the Equator® head was in the area of the lower right canine and dislodgement of Equator® screw area occurred at the lower left canine and affected the fit of the overdenture, producing soft tissue swelling around the SDI (Fig. 3). The patient was initially lost to follow-up after 18 months.

Prosthetic maintenance procedures

After prosthetic delivery, types of prosthetic maintenance procedures were recorded (Table 5). All overdentures remained functional at follow-up. Time from the date of overdenture delivery to follow-up ranged from 3 to 45 months, and the most frequent maintenance process required was occlusal adjustment (72.7%) (Fig. 4). Tissue surface adjustment (6.8%) was performed due to pain and discomfort. This was most clearly presented in a case with severe deformation of the Equator® matrices, which affected support of the overdenture. Denture base repair occurred in 3 (6.8%) overdentures, due to fracture of the acrylic resin over the metal housing (Fig. 5). Artificial

Prosthetic maintenance procedure	Overdenture (%)
None	4 (9.1)
Occlusal adjustment	32 (72.7)
Tissue surface adjustment	3 (6.8)
Denture base repair	3 (6.8)
Artificial teeth addition	1 (2.3)
Artificial teeth repair	1 (2.3)
Total	44 (100)
**Among 38 overdentures, 6 underwent more than one prosthetic maintenance procedure.*	

TABLE 5 Prosthetic maintenance procedures (38 overdentures) *.

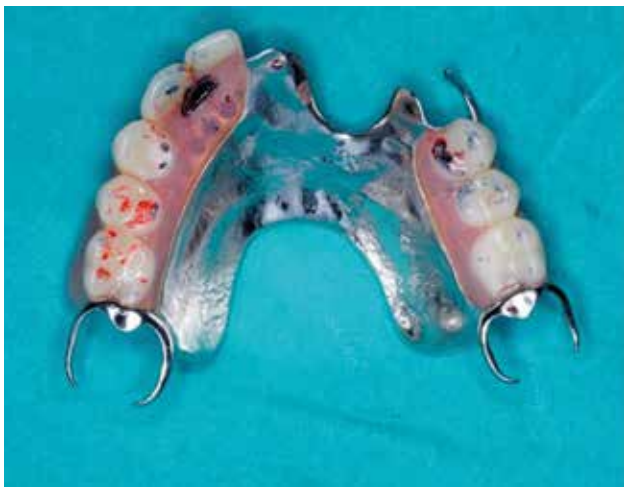

FIG. 4 Image showing the need for occlusal adjustment at follow-up.

FIG. 5 Fracture of the acrylic resin over the metal housing occurred due to inadequate thickness of the acrylic resin in this position.

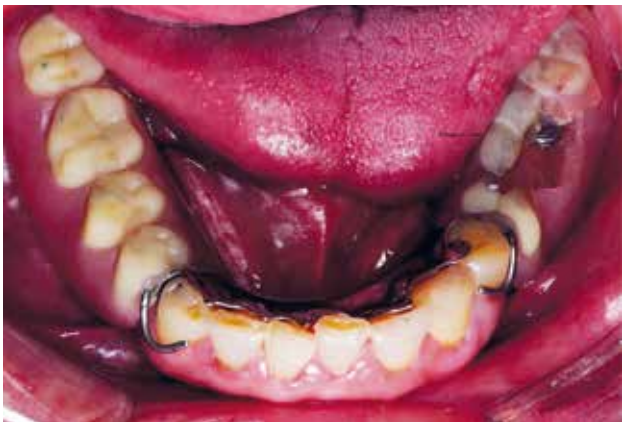

FIG. 6 Acrylic resin tooth fracture of a lower left first molar over the housing, due to inadequate space.

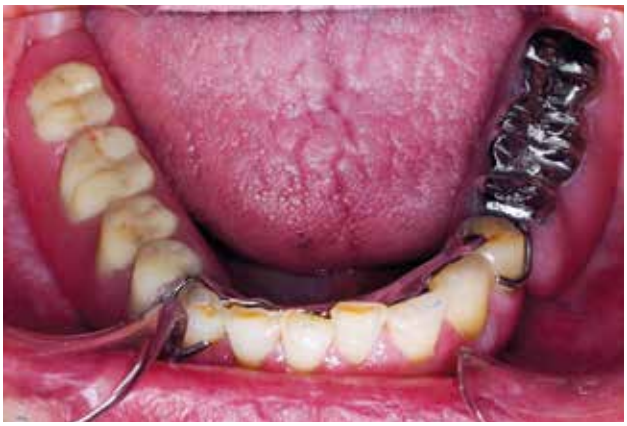

FIG. 7 Image showing the repair of broken acrylic teeth using metal teeth in the lower left area.

tooth fracture (Fig. 6) occurred in 1 (2.3%) overdenture at 21 months after fitting. The thickness of the acrylic resin above the metal housing was found to be inadequate. The researcher repaired the overdenture using metal teeth (Fig. 7).

DISCUSSION

The application of SDI as retentive features for removable prostheses has dramatically increased. The use of SDI for retained overdenture is appropriate for patients with restrictive conditions, such as narrow ridges, limited finances, and geriatrics with relevant medical history, as they can be used to place implants by flapless surgery and provide reduced discomfort and pain. The disadvantages of SDI with respect to conventional implantation include lower fracture resistance and the fact that it is not recommended to place them immediately after tooth extraction. Further, when using flapless surgery, bone morphology is invisble and the surgeon cannot determine bone volume by performing alveoloplasty (14-16).

Many factors are associated with high SDI survival rates. The conventional loading protocol, which is conducted 2 months after implant placement, appears to result in fewer implant failures compared with immediate loading (17). There is also evidence that implants ≥ 10 mm in length result in higher survival rates than shorter implants (18, 19). Resilient attachments tend to reduce the force transmitted to the implant fixture relative to attachments with higher profile, non-resilient designs (20).

In the present study we recorded a 98.3% survival rate of SDI-retained overdentures using a conventional loading protocol, over time periods ranging from 6 to 55 months. This is similar to a preliminary prospective clinical study conducted in 2017, which reported a 6-month survival rate of 93.3% for immediate loading of mini-implants (diameter 3 mm) to retain a mandibular Kennedy Class I removable partial denture (21).

In 2013, a systematic review by Bidra and Almas determined that the 4-year cumulative survival rate of mini-implants for definitive prosthodontic treatment was 92.8% (5). Another systematic review, by Schiegnitz and Al-Nawas (2018), evaluated the survival rate of narrow-diameter implants (3 to 3.25 mm) and found a 97.3% survival rate after a mean follow-up of 29 months; however, the implants were mainly used in final restoration of single teeth in the anterior region (16). It can be concluded that the use of both MDI and SDI results in high survival rates.

In this study, we found that 2 of 119 SDIs (1.7%) failed in the first and third months after implantation during the osteointegration period, due to peri-implantitis. No implant failed after loading of prosthesis. This result is consistent with the findings of Goodacre et al., who concluded that implant loss is more common before than after prosthesis loading (22).

Peri-implantitis is a multifactorial disease, and its possible risk factors include smoking, implant malposition, diabetes mellitus, lack of prophylaxis, inadequate plaque control, periodontal disease, and history of periodontitis. Further, occlusal overload can contribute to peri-implantitis onset and progression (23-25). There is little evidence to support absence of keratinized mucosa, implant surface characteristics, or edentulism as risk factors for peri-implantitis (23, 24). We speculate that failure of implants recorded in this study may have been contributed to by peri-implantitis and other factors, such as parafunctional habit, previous anatomic bone defect, diabetes mellitus, and history of chronic periodontitis. These data suggest that, during the osseointegration period, overloading from the occlusal force around implants should be avoided. During the follow-up period, 1 of 119 (0.8%) of the survived SDIs developed a complication (peri-implantitis) in the second month after overdenture loading due to traumatic

occlusion. Potentially associated factors included diabetes mellitus and history of chronic periodontitis. After mechanical debridement, antiseptic cleaning, and occlusal adjustment, the implant condition was stable and it survived in the mouth.

Attachment complications and prosthetic maintenance procedures of small-diameter implant-retained overdentures

In this study attachment complications occurred from 3 to 45 months after overdenture delivery, including frequent deformation of Equator® matrices (34.4%). An *in vitro* study (26) showed that the retention force of Equator® matrices in mandibular implant-supported overdenture loss is 33.08% after 5,500 insertion-removal cycles (to simulate function over 5 years, with three insertion-removal cycles per day). Nonetheless, clinical studies report complications after a shorter time period than that determined in the *in vitro* study, which simulated a mono-directional vertical force. In contrast, in the clinical situation, deformation can be more strongly influenced by horizontal and lateral forces resulting from functional load (26). Hence, patients should be informed about retention loss and the wear characteristics of the attachment. In this study, deterioration of the Equator® matrices was commonly found at 6–8 months follow-up. These data indicate, that recall for maintenance every 6 months should be recommended.

In this study, wear of metal housing occurred in two patients and may have been caused by chewing hard food. Kabbua and colleagues found that, after the first year of function, the maximum occlusal contact force of overdenture could be increased significantly more than before using SDI-retained overdenture. SDI-retained overdenture improved the functional capacity of dentures and enhanced overall patient satisfaction and quality of life (27). Patients should be advised to use dentures with care, to prevent wear of attachment components and other related complications.

We also found loss of screw preload in 14% of SDIs. While the prosthesis is in use, the occlusal load encourages misfit of the implant-abutment connection (28). Retorque application can increase screw joint stability, reducing attachment and prosthetic complications, such as screw loosening, screw dislodgement, misfit dentures, and change in occlusion, among others. Thus, routine retorque of abutment screws is advisable. Further, the findings of wear of the Equator® head and dislodgement of the Equator® screw in the same individual who was lost to follow-up after 18 months underline the importance of routine follow-up for cases with SDI-retained overdenture.

Need for occlusal adjustment is commonly found during routine denture checkup and was the most frequent prosthetic maintenance procedure recorded in this study (72.7%). According to Kabbua and colleagues, assessment of SDI-retained mandibular overdenture function at six months showed that the number of tooth contacts and degree of force distribution values were slightly decreased due to deterioration of the retentive caps (27). Hence, when occlusion alteration occurs, change of the retentive caps (when they are worn) and occlusal adjustment are generally required. Occurrence of artificial tooth fracture occurred in one overdenture in this study, likely due to inadequate thickness of the acrylic resin above the metal housing. The minimum recommended thickness for a denture base is 2 mm (29), with at least 3 mm suggested for acrylic resin teeth, to prevent their fracture and that of the denture component in cases with overdenture (30). This incident serves as a reminder that adequate inter-arch space is a criterion requiring consideration. Inadequate interocclusal space can result in problems with the prosthesis, such as over-contour, fracture of teeth above the attachments, fracture, and overall patient dissatisfaction (31). Appropriate management, including increase of the vertical dimension, occlusal plane alteration, alveolar ridge reduction, and attachment selection, should be provided, to improve prosthodontic condition (32). It is generally accepted that the use of reduced size attachment (Equator®, low profile attachment) is useful when prosthetic space is compromised (20). Analysis of the pre-prosthetic space, proper management, and provision of information to patients regarding the potential for future problems should also be considered in cases receiving SDI-retained overdenture.

A limitation of this study is the relatively low number of patients and short evaluation of SDI survival rate; hence further studies with higher sample size and longer follow-up periods are necessary.

CONCLUSION

The results of this study suggest that SDI-retained overdenture is a successful treatment modality with a high implant survival rate (98.3%) within a follow-up period of ≤ 4.5 years. Nevertheless, routine checkup every 6 months is crucial for long-term survival of SDI and prostheses. Patients should be strongly advised regarding the proper maintenance procedures and given instructions to prevent complications. Long-term follow up is suggested to further evaluate the clinical outcomes of SDI-retained overdenture.

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Data availability statement

The data sets used and/or analyzed during the current

study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of Faculty of the Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board (Certificate no. COA.No.MU-DT/PY-IRB 2019/028.1305). Written consent was obtained from all participants.

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Conflict of interest:

The authors declare no conflicts of interest.

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