

## ORIGINAL ARTICLE OPEN ACCESS

# A Retrospective Study of Stabilizing Bridges in Patients With Stages III and IV Periodontitis: Up to 35 Years of Clinical Audit

Øystein Fardal<sup>1,2,3</sup>  | Jostein Grytten<sup>2,4</sup>

<sup>1</sup>Private Practice, Egersund, Norway | <sup>2</sup>Institute of Community Dentistry, University of Oslo, Oslo, Norway | <sup>3</sup>Institute of Education for Medical and Dental Sciences, University of Aberdeen, Aberdeen, Scotland | <sup>4</sup>Division of Obstetrics and Gynaecology, Akershus University Hospital, Lørenskog, Norway

**Correspondence:** Jostein Grytten ([j.i.grytten@odont.uio.no](mailto:j.i.grytten@odont.uio.no))

**Received:** 24 August 2024 | **Revised:** 16 December 2024 | **Accepted:** 20 December 2024

**Funding:** The authors received no specific funding for this work.

**Keywords:** advanced periodontitis | clinical audit | cross-arch bridges | implants | prognostic factors | retrospective study | tooth loss

## ABSTRACT

**Background/Aim:** Studies on large cross-arch bridges in patients with severe periodontitis show that such bridges can stabilize the periodontal condition. However, it is not known if these bridges will reduce long-term tooth loss and what factors are important for their long-term survival. The aim of the study was to study all patients with Stages III/IV periodontitis who received cross-arch bridges for up to 35 years in a private practice.

**Materials and Methods:** All patients referred for periodontal treatment from 1986 who received cross-arch bridges with observation period of minimum 7 years were assessed. All dropouts were accounted for.

**Results:** Ninety-eight patients (1.7% of the patient population) with 111 bridges were observed (57 females and 37 males). Age at bridge construction was 55.4 years (SD = 7.1, range 39–79). Failure rate was 14.4% at 16.1 years (SD = 4.0 range 10–22). Reasons for failure were poor oral hygiene ( $p = 0.0093$ ) and complications such as caries, endontics, porcelain fractures and gingival retractions during maintenance therapy ( $p = 0.0059$ ). Fewer abutment teeth were lost from the bridges than teeth from the same and opposing arches (8.8% vs. 34.4% and 25.4%) ( $p < 0.0001$ ).

**Conclusion:** Cross-arch bridges constructed for patients with Stages III and IV periodontitis were successful in terms of longevity, low failure rates, tooth preservation and patient satisfaction.

## 1 | Introduction

Large bridges constructed for patients with severe periodontal disease can last for many years and help stabilize the periodontal condition (Nyman and Lindhe 1979; Fardal and Linden 2010; Graetz et al. 2013; Rădulescu et al. 2022). However, in spite of their high success rate and therapeutic importance, still a number of questions remain: Do they prevent/reduce further tooth loss? When do the bridges fail? What are the reasons for failure? Are there any predictors for the failures? What proportion of patients are suitable for this treatment? Are the patients satisfied?

Patients treated for severe periodontitis (Stages III/IV) undergo active periodontal therapy followed by maintenance therapy. A few patients experience increased tooth mobility and tooth loss in spite of the treatment (Fardal and Linden 2008). The tooth loss may require prosthetic replacements with removable dentures, tooth-supported bridges, single implants, implant bridges or a combination of these.

For some patients it may be beneficial to both replace lost teeth and stabilize the remaining teeth in large cross-arch fixed bridges. Recently, the European Federation of Periodontology

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial](https://creativecommons.org/licenses/by-nc/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

© 2025 The Author(s). *Journal of Clinical Periodontology* published by John Wiley & Sons Ltd.

(EFP) S3 level clinical practice guideline on treatment of Stage IV periodontitis has recommended constructing these types of bridges for some patients (Herrera et al. 2022).

Not all patients are suitable for this treatment, as the location, status, periodontal support and the number of remaining teeth, patient preferences, aesthetic/anatomical challenges and financial constraints can be limiting factors.

A number of complications associated with large bridges have also been described, such as tooth and root fractures, metal and porcelain fractures, endodontic problems, caries, tooth intrusion and tooth loss (Raustia, Närpänkangas, and Salonen 1998; Hämmerle et al. 2000; Owall and Cronström 2000; Goodacre et al. 2003; Walton 2003; Alenezi and Aloqayli 2023). In addition, the use of distal cantilevers has been associated with higher failure rates (Sharma et al. 2012).

Using implants as added support for stabilizing bridges is controversial. This is due both to the use of implants in patients with a history of periodontitis and to combining teeth and implants in fixed bridges (Hardt et al. 2002; Wennström et al. 2004; Roos-Jansåker et al. 2006; Karoussis, Kotsovilis, and Fourmouis 2007; Fardal and Linden 2008; Hosny et al. 2000; Brägger et al. 2001; Naert et al. 2001; Block et al. 2002; Lang et al. 2004; Cordaro et al. 2005; Nickenig, Schäfer, and Spiekermann 2006; Pjetursson et al. 2007; Monje et al. 2014).

Although studies on cross-arch bridges report high levels of success, few details are available on the levels and reasons for failures (Nyman and Lindhe 1979; Fardal and Linden 2010; Graetz et al. 2013; Rădulescu et al. 2022). To obtain information on the failures, the bridges need to be observed until a number of them start to fail to allow for a comparison between these and the surviving bridges.

A 10-year retrospective study has reported on cross-arch bridges constructed for patients during periodontal maintenance treatment in a private practice (Fardal and Linden 2010). Following these patients for up to 35 years would provide a unique opportunity to assess the long-term outcomes for both the bridges and the patients.

The aim of this study was to follow the original 77 patients with 98 bridges in addition to all subsequent patients with the same inclusion requirements for up to 35 years as a quality control measure for this practice. The hypothesis was that cross-arch stabilizing bridges can last for a long time and reduce further tooth loss.

## 2 | Materials and Methods

### 2.1 | Study Population

All patients retrospectively diagnosed with Stages III and IV periodontitis and receiving stabilizing bridges between 1986 and 2016 were identified for inclusion in the study. The inclusion criteria were as follows: (1) Steps 1, 2, 3 periodontal treatment

according to the 2020 EFP guideline; (2) Construction of a cross-arch fixed bridgework by the referring dentist or a specialist in prosthodontics; (3) Each bridge engaging at least the canine teeth bilaterally; (4) Bridges constructed on teeth or on a combination of teeth and implants; (5) Observation period of at least 7 years.

Gender, age, medical history including smoking, close relatives (parents, children, brothers or sisters) with a history of periodontal diseases were recorded. All patient data were de-identified. Probing depths using a Hu-Friedy (Williams) periodontal probe were measured at six locations around each tooth. Panoramic, periapical and bite-wing radiographs were recorded, as well as the total number of teeth. The descriptions by Papapanou et al. (2018) were used to establish Stages III and IV periodontitis.

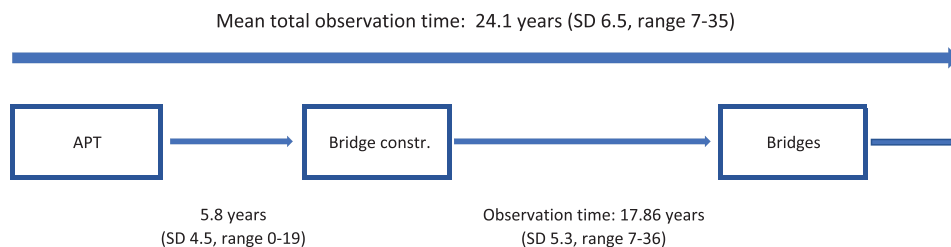
#### 2.1.1 | Periodontal Treatment and Maintenance

The principal investigator (Ø.F.) is a specialist certified by the Norwegian Department of Health and Social Services and is the only periodontal specialist in the area. The specialist practice was started in 1986 and receives referrals from general dental practitioners, community dentists and physicians in Norwegian rural communities with a total population of 25,000–30,000. The area has approximately 25 dentists.

All the patients who were provided with bridgework underwent a similar course of conventional periodontal treatment. Following the initial examination, a diagnosis and a treatment plan were made. The initial treatment plan consisted of active periodontal treatment (APT) including control of individual biofilm control and risk factors (Step 1), non-surgical treatment (Step 2) and, if required, surgery (Step 3). On completion of ATP, the patients were placed on a maintenance programme which was shared with the referring dentist usually from two to four times a year. The patients who received stabilizing bridges had lost teeth and/or had increasing mobility on several teeth during maintenance therapy.

Ninety-four patients (57 females and 37 males) with 111 bridges were observed. This was 1.7% of the total patient population ( $n = 5436$ ). Ninety bridges were teeth-supported and 21 were a combination of teeth and implants. Seventy-six patients (80.9%) had bridges in one arch and 18 (19.2%) had bridges in both arches. Seventy-seven bridges were constructed in the maxillary arch and 34 in the mandibular arch. The average bridge span was 10.2 units (SD = 2.2, range 6–14).

At the initial periodontal examination, the patients' mean age was 49.7 years (SD = 8.6, range 29–74). The mean age at time of bridge construction was 55.4 years (SD = 7.1, range 39–79). The average time between the initial periodontal examination and the construction of the bridges was 5.8 years (SD = 4.5, range 0–19 years). The mean age of the patients at the reassessment of the bridges was 73.7 years (SD = 7.3, range 52–90), resulting in an average bridge observation period of 17.9 years (SD = 5.3, range 7–32). The average patient observation period from initial periodontal examination was 24.2 years (SD = 6.5, range 9–35) (Figure 1).



**FIGURE 1** | Flow diagram of the mean observation period including active periodontal therapy (APT), time of bridge construction and bridge observation.

The total number of teeth at the initial examination was 2077 (average 22.1 teeth per patient, SD = 4.8, range 8–30). After 249 teeth were extracted, there were 1828 teeth left at the construction stage of the bridges. There were 66 implants distributed in 22 patients. The patients who were provided with bridges retained by a combination of teeth and implants had significantly fewer teeth at baseline than those who received bridges with only teeth as abutments (17.9, SD = 4.4, range 8–26 vs. 23.2, SD = 4.3, range 11–30).

## 2.2 | Bridge Design

The designs of the bridges were based on the number of teeth remaining, the periodontal status of the teeth and whether strategic implants could or should be placed to provide sufficient support. All bridges were designed with rigid components, with no stress breakers, and were cemented.

The total number of teeth and implants for the bridges were recorded, in addition to the distribution of tooth abutments, implant abutments, mobile teeth of at least Grade II and pontic units. No patients with combination therapy involving partial dentures were included.

The distribution of tooth abutments, implant abutments, mobile teeth and pontics at the time of bridge construction is shown in Table 1. The upper canines were the most frequent abutments, while the upper premolars were the teeth most frequently replaced. The ratio of tooth abutments to pontic units was 3.4 for the teeth-supported bridges and 3.2 for bridges supported by teeth and implants. Mobility of teeth with at least grade II was present in 17.2% of the tooth-supported bridges and in 20% of the teeth- and implant-supported bridges. The ratio of non-mobile to mobile abutments for bridges supported by teeth was 4.8, and it was 4.0 for the bridges supported by both teeth and implants.

## 2.3 | Accounting for All Patients

The dropouts were recorded with reasons. In addition, all patients who died during the observation period were recorded.

## 2.4 | Accounting for All Bridges and Failures

All bridges lost in drop-out patients, deceased patients and failed bridges were recorded with the number of observation

years. Any reduction in bridge span due to loss of abutment teeth/implants was recorded. Technical and biological complications during the observation period were identified. Loss of abutments was recorded with the reasons. The complications assessed were caries, secondary caries, continued periodontal breakdown measured by increasing periodontal pockets and radiographic bone loss, traumatic events, porcelain and or metal fractures, gingival retractions/aesthetic problems, total number of bridges fractured and endodontic complications.

Periodontal probing was performed at the maintenance visits, and new detailed radiographs were, in general, obtained every 5–6 years.

## 2.5 | Bridge Design and Failures

The use of distal cantilevers and combinations of teeth and implants were examined to assess their failure rates.

## 2.6 | Prognostic Factors for Losing Bridges

The bridges that failed were compared with the those that were still intact using 18 prognostic factors: gender, age at initial periodontal examination, age at bridge construction, diabetes, cardiovascular disease, family history of periodontal disease, dry mouth/drug-induced dry mouth and compliance (complete: compliant with the prescribed maintenance programme; erratic: not compliant regarding the frequencies of maintenance visits or leaving and returning for re-treatment/maintenance treatment). The oral hygiene status was determined as follows: good, that is, little or no generalized plaque and no gingival inflammation; moderate, that is, the generalized presence of minor amounts of plaque (not covering more than one-third of the buccal/lingual surfaces from the gingival margin) with bleeding on probing (BOP), or isolated areas of abundant plaque (covering more than one-third of the buccal/lingual surfaces) with BOP; poor, that is, generalized abundant plaque (covering more than one-third of the buccal/lingual tooth surfaces) with BOP. The scores were recorded at every maintenance visit, and the overall oral health status was the majority score (Fardal, Johannessen, and Linden 2004): smoking (> 10 cigarettes) at the initial examination, re-treatment of periodontal disease, average number of bridge units, proportion of abutments to total units, proportion of abutments with mobilities to total units, proportion of combined bridges to tooth supported bridges, proportion of bridges with distal cantilevers and bridge complications during maintenance treatment.

**TABLE 1** | (A) Distribution of tooth abutments, pontic units and tooth mobility (before bridge insertion) for 90 cross-arch stabilizing bridges supported by teeth only. (B) Distribution of tooth and implant abutments, pontic units and tooth mobility (before bridge insertion) for 21 cross-arch stabilizing bridges supported by a combination of teeth and implants.

		Numbers													
<b>(A)</b>															
Upper jaw	<i>n</i>														
Tooth abutments	485	11	23	24	35	57	50	47	47	41	56	35	26	24	9
Pontic units	125	0	7	19	15	0	6	11	11	17	1	15	16	4	3
Mobility	96	0	2	4	7	3	16	18	17	12	2	8	4	3	0
Type of tooth		7	6	5	4	3	2	1	1	2	3	4	5	6	7
Tooth abutments	211	2	2	15	20	27	22	16	11	22	30	25	16	2	1
Pontic units	82	0	5	3	4	3	9	14	19	9	1	1	7	6	1
Mobility	24	0	3	1	1	3	2	4	2	1	4	2	1	0	0
Lower jaw	<i>n</i>														
<b>(B)</b>															
Upper jaw	<i>n</i>														
Tooth abutments	80	0	3	0	2	11	9	13	10	8	10	6	4	4	0
Pontic units	40	0	1	11	1	0	2	0	2	4	3	6	7	3	0
Implant abutments	56	0	0	3	12	7	6	6	4	5	6	6	1	0	0
Mobility	26	0	0	0	1	3	1	5	4	4	5	2	1	0	0
Type of tooth		7	6	5	4	3	2	1	1	2	3	4	5	6	7
Tooth abutments	24	1	0	0	0	2	3	3	2	3	4	3	1	1	1
Pontic units	12	0	3	3	1	0	0	1	2	0	0	0	2	0	0
Implant abutments	10	0	0	1	3	2	1	0	1	0	2	0	0	0	0
Mobility	8	0	0	0	0	1	3	2	1	0	0	0	1	0	0
Lower jaw	<i>n</i>														

## 2.7 | Tooth Loss From the Bridges Compared With the Rest of the Same Arch and the Opposing Arch

For each patient, abutment tooth loss was compared with tooth loss from the remaining teeth in the same arch and from the opposing arch.

## 2.8 | Patient Satisfaction

As part of a clinical feedback and quality control of the treatment, patients were interviewed at the maintenance treatment sessions about their bridges in terms of function, aesthetics and/or discomfort. They were asked the following questions: (1) Are you satisfied with the bridge? (2) Have you any functional issues? (3) Have you any aesthetic issues? (4) Have you any discomfort associated with the bridge(s)? If the answer to question (1) was no, or if the answers to questions (2–4) were yes, the patients were interviewed in depth to identify the exact clinical problem(s) in order to have it (them) rectified. The responses and treatments if required were entered into the patients records.

### 2.8.1 | Statistical Analysis

Descriptive statistics are presented as means, standard deviations and range. Some results were reported as proportions. Student's *t*-test was used for data that were normally distributed; otherwise, the Mann–Whitney *U* test was applied.  $\chi^2$  analysis was used for categorical data. The level of significance was set at  $p < 0.05$ .

### 2.8.2 | Ethical Approval

The project (821006) was considered exempt from review/submission by/to the Regional Committee for Medical and Health Research Ethics.

## 3 | Results

### 3.1 | Bridge Failures and Dropouts

Bridge failures and dropouts are shown in Figure 2.

3.1.1 | Bridge Failures

The average observation time for the 111 bridges was 17.9 years (SD=5.3, range 7–36). Figure 3 shows the number of observation years for all of the 111 bridges.

Sixteen bridges (14.4%) failed after 16.1 years (SD=4.0, range 10–22). The reasons for failures were as follows: Seven bridges failed as a result of caries and five because of a combination of continued periodontal breakdown and caries; two were lost because of trauma; one bridge fractured and one bridge was lost because of caries and endodontic complications. The 16 failed

bridges were replaced by 4 tooth-supported bridges, 2 implant bridges, 1 combination tooth implant bridge, 3 partial dentures and 6 full dentures.

3.1.2 | Dropouts

Twenty-one patients with 25 bridges dropped out of the maintenance treatment after 14.9 years (SD=5.2, range 7–31). Two bridges were lost and two bridges were shortened. The dental office lost contact with 18 of these patients, 1 moved out of the area and 2 were institutionalized.

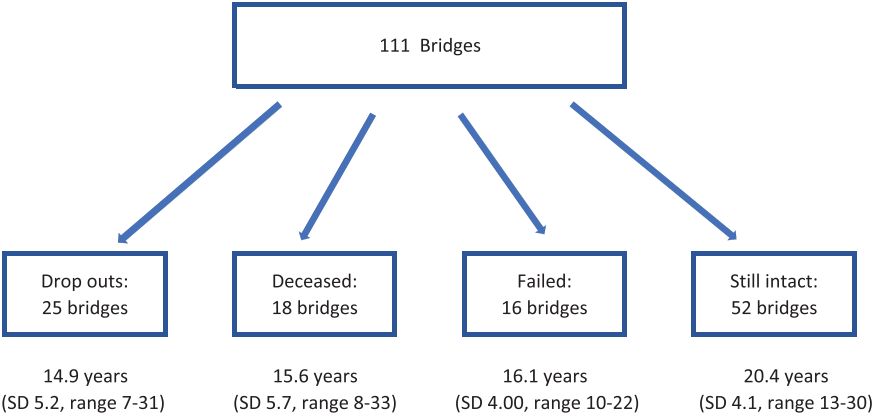


FIGURE 2 | The initial 111 bridges with dropouts, deceased patients and failed bridges.

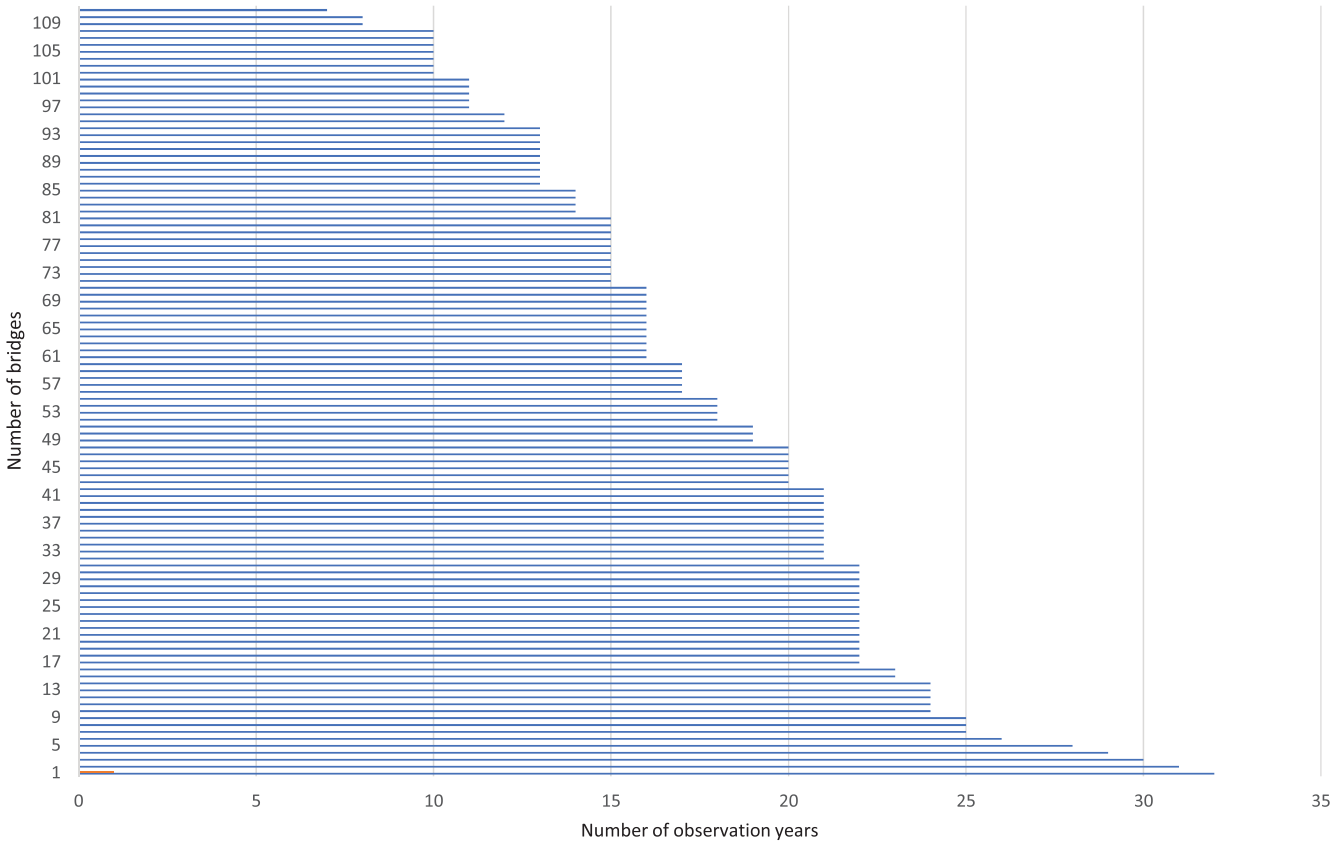


FIGURE 3 | Number of observation years for each of the 111 bridges.



### 3.1.3 | Deceased

Fourteen patients with 18 bridges died after 15.6 years (SD = 5.7, range 8–33). One bridge in one patient who had two bridges had failed before death; for the rest, the bridges were intact at time of death as far as could be confirmed.

### 3.1.4 | Data From Dropouts and Deceased Patients

Patients' data were collected for both dropouts and deceased until the maintenance treatment was terminated. The overall results for the 111 bridges thus include the full dataset from these two categories.

### 3.1.5 | Bridge Reductions

Nine bridges were reduced in size as a result of tooth or implant loss, ending up with 76.4% (SD = 15.0 range 50–92) of the original bridge units.

## 3.2 | Bridge Design and Failures

### 3.2.1 | Distal Cantilevers

Thirty-seven (33.3%) patients had posterior cantilever extensions, 19 unilaterally and 18 bilaterally (55 distal extensions in total). Thirty-eight were opposed by natural teeth, crowns or pontics, one was opposed by a complete denture and the remainder were non-opposed. Six bridges (16%) with distal cantilevers failed after 14.2 years (SD = 2.5, range 10–17).

### 3.2.2 | Combination Bridges Using Teeth and Implants

There were 21 combination bridges; 3 of these (14.0%) failed after 14, 15 and 16 years, respectively. In addition, one bridge was reduced to 9/12 (75%) of the original size. Two implants (3.0%) were lost, one after 13 years and one after 15 years. In addition, six patients had peri-implantitis.

## 3.3 | Risk Indicators for Losing Bridges

As shown in Table 2, the 16 bridges that failed were compared with the 52 intact bridges using 18 different prognostic factors. Two were statistically significant: (1) A high level of complications during the maintenance therapy ( $p = 0.0059$ ). These complications were related to caries, endontics, porcelain fractures and gingival retractions. (2) Poor oral hygiene ( $p = 0.0093$ ).

## 3.4 | Tooth Loss From the Bridges Compared With the Rest From the Same Arch and Opposing Arch Using Internal Patient Controls

Five-hundred and sixty-six teeth were lost in total (average 6.0 teeth, SD = 4.7, range 0–22) (Table 3). Two-hundred and forty-nine of these were removed before the bridges were made. There

were 1828 teeth when the bridges were made. The tooth loss was as follows: 8.9% of the abutment teeth were lost; 34.4% of the teeth were lost from the same arch not covered by the bridge; 25.4% of the teeth were lost in the opposing arch. Tooth loss from the bridges was significantly lower ( $p < 0.0001$ ) than both from the same arch and the opposing arch.

## 3.5 | Tooth Loss in Patients With the Intact Bridges

Fifty-two bridges were still intact at the end of the observation period (20.4 years, SD = 4.3, range 13–30). The initial number of teeth present was 21.9 (SD = 5.1 range 8–29). Average tooth loss before bridges were constructed was 2.6 (SD = 2.8, range 0–15). Total tooth loss was 4.1 (SD = 3.5, range 0–18). The number of abutments lost was 0.5 (SD = 0.5, range 0–1).

## 3.6 | Patient Satisfaction

The patients were satisfied with both the function and aesthetics of the bridges. One patient was not happy with contours of the upper anterior teeth; however, he did not want or request a remake. The patients were not concerned about the gingival retractions. They seem to think that this was inevitable and part of the cost of keeping the bridges over so many years.

## 4 | Discussion

This study included all cross-arch bridges constructed for patients with periodontitis Grades III and IV in a private practice with observations of up to 35 years. The construction of the bridges is in line with the recent recommendations by the EFP for patients with periodontitis Stage IV with a sufficient number ( $\geq 4$  abutment teeth) of periodontally maintainable, bilaterally distributed and restorable teeth in the maxilla and/or mandible (Herrera et al. 2022).

The results confirm the short- and long-term success of these bridges (Nyman and Lindhe 1979; Fardal and Linden 2010; Graetz et al. 2013; Rădulescu et al. 2022). Only 14.4% of the bridges failed after an average of 16 years. The prognostic factors were poor oral hygiene and complications during the maintenance treatment.

It was found that the bridges reduced further tooth loss and that the patients were satisfied with the treatment. Combining teeth and implants did not have a negative effect on the success of these bridges, as the failure rate was 14.0%. This finding is supported by previous studies by Fardal and Linden (2010) and Guarnieri et al. (2019). However, Lang et al. (2004) and Pjetursson et al. (2007) have reported lower success rates for these types of bridges.

The use of distal cantilevers was associated with higher failure rates, which is in agreement with Sharma et al. (2012). However, considering the failure was only 16% after 14.2 years, this design does not represent a significant clinical risk if other options are not possible.

The low failure rate for the large bridges is in contrast to the findings of Alenezi and Aloqayli (2023) who reported a failure

**TABLE 2** | Comparing 18 prognostic factors between the intact and failed bridges.

Prognostic factors	Intact bridges ( <i>n</i> = 52)		Failed bridges ( <i>n</i> = 16)		<i>p</i>
	Number/total	Percent/mean	Number/total	Percent/mean	
Females	29/49	59.2%	9/14	64.3%	0.73
Age at initial periodontal examination	—	49.0 (SD 8.1)	—	50.8 (SD 9.3)	0.47
Age at bridge construction	—	54.9 (SD 6.9)	—	56.7 (SD 7.5)	0.39
Diabetes	3/49	6.1%	2/14	14.3%	0.32
Cardiovascular disease	8/49	16.3%	4/14	28.6%	0.30
Family history of periodontal disease	19/49	38.8%	6/14	42.9%	0.78
Dry mouth/drug-induced dry mouth	1/49	2.0%	0/14	0.0%	0.59
Erratic compliance	1/49	2.0%	1/14	7.2%	0.34
Poor oral hygiene	1/49	2.0%	3/14	21.4%	0.01
Moderat oral hygiene	30/49	61.2%	7/14	50.0%	0.45
Smoking > 10 cig. at initial examination	27/49	55.1%	10/14	71.4%	0.27
Number of patients at re-treatment	36/49	73.5%	13/14	92.9%	0.12
Average number of bridge units	—	10.3 (SD 2.3)	—	9.3 (SD 2.2)	0.12
Proportion of abutments to total units	406/567	71.1%	111/148	74.9%	0.35
Proportion mobility abutments to total units	69/406	17.0%	23/111	20.7%	0.73
Proportion of combined bridges to tooth-supported bridges	15/55	27.3%	2/16	12.5%	0.22
Proportion of bridges with distal abutments	14/55	25.5%	6/16	37.5%	0.34
Complications during maintenance treatment	9/55	16.4%	8/16	50.0%	0.01

Note: Percent and means (SD). Forty-nine patients.

**TABLE 3** | Comparing tooth loss between the abutment teeth in the bridges, the rest of same arch and the opposing arch.

	Number of patients	Number of teeth	Tooth loss	Tooth loss proportion (%)	Mean (SD)	Range	<i>p</i>
Initial number of teeth	94	2077			22.1 (SD 4.8)	8–30	
Pre bridge construction	82	2077	249	12.0%	2.6 (SD 2.6)	1–15	
Abutment teeth	20	800	71	8.9%	3.6 (SD 2.6)	1–9	
Rest of same arch	15	96	33	34.4%	2.2 (SD 1.3)	1–5	<0.0001
Opposing arch	41	839	213	25.4%	5.2 (SD 3.4)	1–14	<0.0001

rate of 92% for bridges with more than five units after 15 years. However, their inclusion criteria were different and the failures were described as mainly technical, while in the present study the failures were mainly biological. The fact that some bridges were shortened because of distal abutment failure is rarely alluded to. Even with a reduction of 24%, the bridges were still functional and the patients were satisfied.

A systematic review using four studies of tooth-supported full arch bridges with observation periods ranging from 7 to 12 years showed 4.9% tooth loss, 4.6% loss of bridges and 8%

technical complications (Montero et al. 2022). This is lower than in the present study but it is difficult to compare the results because of the shorter observation period reported in the review.

Another review by Tomasi et al. (2022) compared tooth-based bridges with implant-supported bridges. They reported 1% tooth loss and 4% implant loss with 5% bridge loss for tooth-supported and 6% for implant-supported bridges over a 10-year period. At 15 years, tooth loss and tooth-supported bridge loss were 10% and 13%, respectively. The latter results are

similar to those of the present study with 8.9% tooth loss and 14.4% bridge loss, but the present study had a longer observation period.

The systematic review by Tomasi et al. (2022) also reported that technical complications affected 8% of tooth-supported bridges over 7.2 years and 42% of implant structures over 2.6 years. Peri-implantitis were observed in 9% of implants over 3.1 years. This clearly shows that full-arch tooth-supported bridges have much less complications than implant-supported bridges.

Patient satisfaction was good for the bridges in spite of the clinician reporting a high level of gingival retractions. It has previously been shown that clinicians are more critical about aesthetic issues than the patients themselves (Jørnung and Fardal 2007; Moon and Millar 2017). Assessing patient satisfaction is an important part of quality control in the health service (Ferreira et al. 2023).

The design of the cross-arch bridges seems to be well suited for reduced periodontal support on the abutment teeth. However, even though Müller et al. (2013) showed more tooth loss during supportive periodontal care (SPC) in patients with protheses than in a control group without protheses, they could not find significant differences in abutment tooth loss between FDP and removable dental protheses. In contrast, Pretzl et al. (2008) reported that abutment teeth of removable dentures had worse prognosis than abutment teeth of fixed dentures. To avoid another possible variable, no bridge combination with partial removable dentures was considered in the present study.

Finally, the fact that virtually all bridges were in place for the patients who died meant that they provided them with 'teeth for life'. Naturally, this depends on the age of the patient at the time of insertion of the bridges.

There are, however, some limitations associated with this study.

1. The failure rate may be higher than reported, as there were no data on the drop-out patients. However, as the failures occurred at 16.6 years, this would have included the failure data for both the dropouts at 14.9 years and deceased at 15.6 years.
2. Comparing tooth loss from the bridges with tooth loss from the same arch may not give a correct result. As the bridges had on average > 10 units, this would have left mainly molars to be lost provided they were symmetrical. Molars are reported to be the most frequently lost teeth (Hirschfeld and Wasserman 1978; McFall 1982; Fardal et al., 2004; Fardal, Skau, and Grytten 2023). However, as a number of bridges were not symmetrical, there were also a number of molars present. To further confirm the findings, tooth loss was also compared with all teeth in the opposing arch.
3. Poor oral hygiene as a predictor. As there were only a very small number of patients with poor oral hygiene, the clinical significance may not support the statistical significance.

4. A retrospective cohort study cannot produce data quality similar to prospective studies. This is because the variables are not planned ahead of time and that data on confounding factors may be inadequate or missing. Especially, missing data on dropouts is an inherent weakness for retrospective studies. However, in the present study we have presented patient data for both dropouts and those who died during the observation period.

## 5 | Conclusion

Cross-arch bridges constructed for patients with severe periodontitis can successfully replace lost teeth and stabilize the dentition. Although they have low failure rates and the patients seem to be satisfied relatively few patients receive these bridges. This could be due to a high threshold for selecting patients for this treatment.

### Author Contributions

Øystein Fardal made substantial contributions to the conception and design of the work; acquisition, analysis and interpretation of data; and drafting the manuscript and revising it critically for important intellectual content. Jostein Grytten made substantial contributions to the interpretation of the data and revising the manuscript critically for important intellectual content. Both authors have given final approval of the version to be published, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

### Acknowledgements

We thank Irene Skau for help with the technical aspects of the manuscript.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

### References

- Alenezi, A., and S. Aloqayli. 2023. "Technical Complications With Tooth-Supported Fixed Dental Protheses (FDPs) of Different Span Lengths: An up to 15-Year Retrospective Study." *BMC Oral Health* 23: 393. <https://doi.org/10.1186/s12903-023-03121-9>.
- Block, M. S., D. Lirette, D. Gardiner, et al. 2002. "Prospective Evaluation of Implants Connected to Teeth." *International Journal of Oral and Maxillofacial Implants* 17: 473–487.
- Brägger, U., S. Aeschlimann, W. Bürgin, C. H. F. Hämmerle, and N. P. Lang. 2001. "Biological and Technical Complications and Failures With Fixed Partial Dentures (FPD) on Implants and Teeth After Four to Five Years of Function." *Clinical Oral Implants Research* 12: 26–34. <https://doi.org/10.1034/j.1600-0501.2001.012001026.x>.
- Cordaro, L., C. Ercoli, C. Rossini, F. Torsello, and C. Feng. 2005. "Retrospective Evaluation of Complete-Arch Fixed Partial Dentures Connecting Teeth and Implant Abutments in Patients With Normal



- and Reduced Periodontal Support." *Journal of Prosthetic Dentistry* 94: 313–320.
- Fardal, Ø., and G. Linden. 2008. "Tooth Loss and Implant Outcomes in Patients Refractory to Treatment in a Periodontal Practice." *Journal of Clinical Periodontology* 35: 733–738. <https://doi.org/10.1111/j.1600-051X.2008.01247.x>.
- Fardal, Ø., and G. Linden. 2010. "Long-Term Outcomes for Cross Arch Stabilizing Bridges in Periodontal Maintenance Patients—A Retrospective Study." *Journal of Clinical Periodontology* 37: 299–304. <https://doi.org/10.1111/j.1600-051X.2009.01528.x>.
- Fardal, Ø., I. Skau, and J. Grytten. 2023. "A 30-Year Retrospective Cohort Outcome Study of Periodontal Treatment of Stages III and IV Patients in a Private Practice." *Journal of Clinical Periodontology* 52: 102–112. <https://doi.org/10.1111/jcpe.13877>.
- Fardal, Ø., A. Johannessen, and G. J. Linden. 2004. "Tooth Loss during Maintenance Following Periodontal Treatment in a Periodontal Practice in Norway." *Journal of Clinical Periodontology* 31: 550–555. <https://doi.org/10.1111/j.1600-051X.2004.00519.x>.
- Ferreira, D. C., I. Vieira, M. I. Pedro, P. Caldas, and M. Varela. 2023. "Patient Satisfaction With Healthcare Services and the Techniques Used for Its Assessment: A Systematic Literature Review and a Bibliometric Analysis." *Healthcare (Basel)* 11: 639. <https://doi.org/10.3390/healthcare11050639>.
- Goodacre, C. J., G. Bernal, K. Rungcharassaeng, and J. Y. Kan. 2003. "Clinical Complications in Fixed Prosthodontics." *Journal of Prosthetic Dentistry* 90: 31–41.
- Graetz, C., F. Schwendicke, M. Kahl, et al. 2013. "Prosthetic Rehabilitation of Patients With History of Moderate to Severe Periodontitis: A Long-Term Evaluation." *Journal of Clinical Periodontology* 40: 799–806. <https://doi.org/10.1111/jcpe.12124>.
- Guarnieri, R., D. Di Nardo, G. Di Giorgio, G. Miccoli, and L. Testarelli. 2019. "Full Arch Fixed Prostheses vs. Full Arch Telescopic-Retained Retrievable Prostheses Both Supported by Implants and Natural Tooth Abutments in Periodontally Treated Patients: Results at 15 Years." *Journal of Clinical and Experimental Dentistry* 11: e937–e946. <https://doi.org/10.4317/jced.55904>.
- Hardt, C. R., K. Gröndahl, U. Lekholm, and J. L. Wennström. 2002. "Outcome of Implant Therapy in Relation to Experienced Loss of Periodontal Bone Support: A Retrospective 5-Year Study." *Clinical Oral Implants Research* 13: 488–494.
- Herrera, D., M. Sanz, M. Kebschull, et al. 2022. "Treatment of Stage IV Periodontitis: The EFP S3 Level Clinical Practice Guideline." *Journal of Clinical Periodontology* 49, no. Suppl 24: 4–71. <https://doi.org/10.1111/jcpe.13639>.
- Hirschfeld, L., and B. Wasserman. 1978. "A Long-Term Survey of Tooth Loss in 60 Treated Periodontal Patients." *Journal of Periodontology* 49: 225–237. <https://doi.org/10.1902/jop.1978.49.5.225>.
- Hosny, M., J. Duyck, D. van Steenberghe, and I. Naert. 2000. "Within-Subject Comparison Between Connected and Nonconnected Tooth-To-Implant Fixed Partial Prostheses: Up to 14-Year Follow-Up Study." *International Journal of Prosthodontics* 13: 340–346.
- Hämmerle, C. H., M. C. Ungerer, P. C. Fantoni, U. Brägger, W. Bürgin, and N. P. Lang. 2000. "Long-Term Analysis of Biologic and Technical Aspects of Fixed Partial Dentures With Cantilevers." *International Journal of Prosthodontics* 13: 409–415.
- Jørnung, J., and Ø. Fardal. 2007. "Perceptions of Patients' Smiles: A Comparison of Patients' and dentists' Opinions." *Journal of the American Dental Association* 138: 1544–1553; quiz 1613–4. <https://doi.org/10.14219/jada.archive.2007.0103>.
- Karoussis, I. K., S. Kotsovilis, and I. Fourmousis. 2007. "A Comprehensive and Critical Review of Dental Implant Prognosis in Periodontally Compromised Partially Edentulous Patients." *Clinical Oral Implants Research* 18: 669–679. <https://doi.org/10.1111/j.1600-0501.2007.01406.x>.
- Lang, N. P., B. E. Pjetursson, K. Tan, U. Brägger, M. Egger, and M. Zwahlen. 2004. "A Systematic Review of the Survival and Complication Rates of Fixed Partial Dentures (FPDs) After an Observation Period of at Least 5 Years." *Clinical Oral Implants Research* 15: 643–653. <https://doi.org/10.1111/j.1600-0501.2004.01118.x>.
- McFall, W. T., Jr. 1982. "Tooth Loss in 100 Treated Patients With Periodontal Disease: A Long-Term Study." *Journal of Periodontology* 53: 539–549. <https://doi.org/10.1902/jop.1982.53.9.539>.
- Monje, A., G. Alcoforado, M. Padial-Molina, F. Suarez, G. H. Lin, and H. L. Wang. 2014. "Generalized Aggressive Periodontitis as a Risk Factor for Dental Implant Failure: A Systematic Review and Meta-Analysis." *Journal of Periodontology* 85: 1398–1407. <https://doi.org/10.1902/jop.2014.140135>.
- Montero, E., A. Molina, D. Palombo, B. Morón, G. Pradies, and I. Sanz-Sánchez. 2022. "Efficacy and Risks of Tooth-Supported Prostheses in the Treatment of Partially Edentulous Patients With Stage IV Periodontitis. A Systematic Review and Meta-Analysis." *Journal of Clinical Periodontology* 49: 182–207. <https://doi.org/10.1111/jcpe.13482>.
- Moon, R., and B. Millar. 2017. "Dental Aesthetics: A Study Comparing Patients' Own Opinions With Those of Dentists." *Open Journal of Stomatology* 7: 225–233. <https://doi.org/10.4236/ojst.2017.74016>.
- Müller, S., P. Eickholz, P. Reitmeir, and T. Eger. 2013. "Long-Term Tooth Loss in Periodontally Compromised but Treated Patients According to the Type of Prosthodontic Treatment. A Retrospective Study." *Journal of Oral Rehabilitation* 40: 358–367. <https://doi.org/10.1111/joor.12035>.
- Naert, I. E., J. A. J. Duyck, M. M. F. Hosny, and D. Van Steenberghe. 2001. "Freestanding and Tooth-Implant Connected Prostheses in the Treatment of Partially Edentulous Patients." *Clinical Oral Implants Research* 12: 237–244. <https://doi.org/10.1034/j.1600-0501.2001.012003237.x>.
- Nickenig, H.-J., C. Schäfer, and H. Spiekermann. 2006. "Survival and Complication Rates of Combined Tooth-Implant-Supported Fixed Partial Dentures." *Clinical Oral Implants Research* 17: 506–511. <https://doi.org/10.1111/j.1600-0501.2006.01259.x>.
- Nyman, S., and J. Lindhe. 1979. "A Longitudinal Study of Combined Periodontal and Prosthetic Treatment of Patients With Advanced Periodontal Disease." *Journal of Periodontology* 50: 163–169.
- Owall, B., and R. Cronström. 2000. "First Two-Year Complications of Fixed Partial Dentures, Eight Units or More. Swedish Guarantee Insurance Claims." *Acta Odontologica Scandinavica* 58: 72–76.
- Papapanou, P. N., M. Sanz, N. Buduneli, et al. 2018. "Periodontitis: Consensus Report of Workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions." *Journal of Clinical Periodontology* 45: S162–S170. <https://doi.org/10.1111/jcpe.12946>.
- Pjetursson, B. E., U. Brägger, N. P. Lang, and M. Zwahlen. 2007. "Comparison of Survival and Complication Rates of Tooth-Supported Fixed Dental Prostheses (FDPs) and Implant-Supported FDPs and Single Crowns (SCs)." *Clinical Oral Implants Research* 18, no. Suppl 3: 97–113. <https://doi.org/10.1111/j.1600-0501.2007.01439.x>.
- Pretzl, B., J. Kaltschmitt, T.-S. Kim, P. Reitmeir, and P. Eickholz. 2008. "Tooth Loss After Active Periodontal Therapy. 2: Tooth-Related Factors." *Journal of Clinical Periodontology* 35: 175–182. <https://doi.org/10.1111/j.1600-051X.2007.01182.x>.
- Raustia, A. M., R. Nääpänkangas, and M. A. M. Salonen. 1998. "Complications and Primary Failures Related to Fixed Metal Ceramic Bridge Prostheses Made by Dental Students." *Journal of Oral Rehabilitation* 25: 677–680. <https://doi.org/10.1046/j.1365-2842.1998.00277.x>.
- Roos-Jansåker, A. M., C. Lindahl, H. Renvert, and S. Renvert. 2006. "Nine- to Fourteen-Year Follow-Up of Implant Treatment. Part I:

Implant Loss and Associations to Various Factors." *Journal of Clinical Periodontology* 33: 283–289. <https://doi.org/10.1111/j.1600-051X.2006.00907.x>.

Rădulescu, V., M. Boariu, D. Rusu, et al. 2022. "Is the Diagnosis of Generalized Stage IV (Severe) Periodontitis Compatible With the Survival of Extended Stabilizing Prosthetic Restorations? A Medium-Term Retrospective Study." *Diagnostics (Basel)* 12: 3053. <https://doi.org/10.3390/diagnostics12123053>.

Sharma, A., G. R. Rahul, S. T. Poduval, and K. Shetty. 2012. "Assessment of Various Factors for Feasibility of Fixed Cantilever Bridge: A Review Study." *ISRN Dentistry* 2012: 259891. <https://doi.org/10.5402/2012/259891>.

Tomasi, C., J.-P. Albouy, D. Schaller, R. C. Navarro, and J. Derks. 2022. "Efficacy of Rehabilitation of Stage IV Periodontitis Patients With Full-Arch Fixed Prostheses: Tooth-Supported Versus Implant-Supported—A Systematic Review." *Journal of Clinical Periodontology* 49, no. Suppl 24: 248–271. <https://doi.org/10.1111/jcpe.13511>.

Walton, T. R. 2003. "An up to 15-Year Longitudinal Study of 515 Metal-Ceramic FPDs: Part 2. Modes of Failure and Influence of Various Clinical Characteristics." *International Journal of Prosthodontics* 16: 177–182.

Wennström, J. L., A. Ekestubbe, K. Gröndahl, S. Karlsson, and J. Lindhe. 2004. "Oral Rehabilitation With Implant-Supported Fixed Partial Dentures in Periodontitis-Susceptible Subjects: A 5-Year Prospective Study." *Journal of Clinical Periodontology* 31: 713–724.