# Clinical Evaluation of Mandibular Posterior Three-Unit Combined Tooth-/Implant-Supported Fixed Partial Dentures: Controlled Prospective Clinical Study

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***Purpose:*** The aims of the study were to evaluate the clinical performance and the complications of combined tooth-/implant-supported three-unit fixed partial dentures (FPDs) in the posterior mandible. ***Materials and Methods***: A total of 78 partially edentulous patients in the posterior mandible were recruited for the study (n = 26/group). Group 1 served as the control group and received two dental implants to support a three-unit FPD. Groups 2 and 3 were the experimental groups in which one implant was placed in conjunction with support from an adjacent tooth to support a three-unit FPD. Standard implants (≥ 8 mm) were included in Group 2, while short implants (< 8 mm) were included in Group 3. Periapical radiographs were taken for evaluation of crestal bone loss (CBL). Modified plaque index (MPI), bleeding index (BI), and sulcus depth values of the abutment teeth were recorded at the time of FPD delivery, 6 months after FPD delivery, and annually thereafter. Recorded complications included abutment tooth intrusions, cementation failures of the restorations, porcelain chipping/delamination, framework fracture, abutment screw loosening, abutment and abutment screw fracture, and implant fracture. ***Results:*** Statistically significant differences were observed between Group 1 (0.06 ± 0.17) and Group 2 (0.18 ± 0.32) and between Group 1 and Group 3 (0.17 ± 0.30) in terms of MPI ($P \leq .05$). No difference was observed between Group 2 (0.11 ± 0.34) and Group 3 (0.14 ± 0.36) or between Group 1 (0.04 ± 0.22) and Group 2 in terms of BI. There were statistically significant differences in terms of CBL between Group 1 (0.259 ± 0.05 mm) and Group 3 (0.11 ± 0.03 mm) and between Group 2 (0.03 ± 0.03 mm) and Group 3 ($P \leq .05$). The mean abutment tooth sulcus depth was 1.11 ± 0.31 mm for Group 2 and 1.20 ± 0.46 mm for Group 3. ***Conclusions:*** Within the limitations of the current study, it was concluded that combined tooth/implant-supported prostheses (CTISPs) are a predictable treatment choice in the posterior mandible. When a CTISP is planned, it is more predictable to use a short implant than a standard-length implant.
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**Keywords:** combined tooth-/implant-supported prostheses, freestanding dental implants, short dental implant

Tooth loss can be treated predictably with various types of implant-supported prostheses.[1–3] Among these therapies, combined tooth/implant-supported prostheses (CTISPs) are by far the most controversial treatment type in terms of survival of abutment tooth, implant, and restoration.[4,5] CTISPs have offered some advantages over freestanding implant-supported prostheses (FSISPs). First, the patient can be treated with fewer implants, and the need for an augmentation procedure may be eliminated. CTISP may also provide some solutions for avoiding cantilevers and large tissue defects, they can be helpful for splinting mobile teeth, and they can serve as a treatment option for patients who cannot be treated with an FSISP.[6]

However, problems arise in CTISPs due to the differences in support mechanism of the implant and abutment tooth.[7] Periodontal ligaments connect teeth to alveolar sockets, but implants are ankylosed (osseointegrated) to the bone.[3] When subjected to load, the natural tooth can move vertically and horizontally 10 to 20 times more than the osseointegrated implant.[8,9] Thus, when the tooth and implant are connected to support a fixed partial denture (FPD), it has been hypothesized that a cantilever effect occurs on the implant, which is considered a problem.[10] When CTISPs are considered from a mechanical standpoint, some complications may be expected due to the occurrence of moment forces caused by the cantilever. Common complications reported for CTISPs include cementation failures; restoration, abutment, and implant fracture; bone resorption around the implant; and abutment tooth intrusion.[10,11] When a CTISP is planned, some biomechanical factors need to be considered carefully:

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- Mobility degree of the abutment tooth
- Number of abutment teeth to be combined with the implant
- Duration, distribution, direction, and magnitude of the occlusal forces
- Parafunctional behaviors/habits
- Superstructure plan
- Rigidity of the prosthesis
- Connection type of the tooth/implant (rigid or nonrigid connection)
- Bone quality
- Abutment tooth vitality and periodontal health status

These factors may affect the survival of the implant and success of the treatment.[12]

Apart from reviews, meta-analyses, and case reports, the studies in the literature investigating CTISPs have mainly concentrated on photoelastic and finite element analysis (FEA). However, the clinical studies on this topic are mostly retrospective. While prospective controlled clinical trials offer sound clinical evidence,[13,14] they are rare concerning CTISPs. Guarnieri and Ippoliti[15] investigated the long-term clinical performance of periodontally compromised teeth combined with various numbers of implants in full-arch restorations in a retrospective study and reported high survival rates after 15 years if regular periodontal supportive therapy was performed. In a retrospective study, Heinemann et al[16] reported similar bone levels after 2 years between full-arch immediately loaded FSISPs and CTISPs in the maxilla. Another retrospective study was published by Nickenig et al[17] with 83 patients who received CTISPs with 4.73 years' median follow-up time. The group reported mechanical failures (veneer fracture or fracture of framework) in 10% of cases. While all the implants were in function, three of the abutment teeth were lost due to periodontal inflammation.

Two important long-term clinical studies were published consecutively in 2000 and 2001. Hosny et al[18] followed 18 patients who received implant-supported prostheses with and without tooth connection within the same arch for up to 14 years. Implant outcome, marginal bone stability, and mechanical complications were investigated. The group concluded that splinting teeth with implants to support fixed prostheses did not affect the long-term outcome in comparison to freestanding implants. On the contrary, Neart et al[19] connected 339 implants to 313 teeth (test group) and 329 implants to each other (control group) to support FPDs in 246 patients (n = 123) and followed them for 1.5 to 15 years and 1.3 to 14.5 years, respectively. The authors reported 95% implant success rates for the test group and 98.5% for the control group. While 10 implants failed in the test group, only 1 implant failed in the control group. Periapical lesions (3.5%), tooth fracture (0.6%), tooth extraction (1%), tooth intrusion (3.4%), and crown cement failure (8%) were reported as complications in the test group. The authors concluded that the freestanding implant solution must be the primary consideration due to the clear tendency of increased implant failures in CTISPs.

Gunne et al[20] published an interesting 10-year longitudinal study comprised of 23 patients with residual mandibular anterior teeth. One side of the mandible was treated with a two-implant–supported FPD, while the other side was treated with a one-implant-and-one-tooth–supported FPD; this model permitted intraindividual comparison in terms of implant stability, mechanical complications, and marginal bone level. The authors found no difference between groups in complications except for marginal bone level; the bone loss was significantly less around the implants of the CTISPs. Furthermore, in a prospective study with a very limited follow-up period, Mostafaa et al[21] evaluated the performance of three-units FPDs in the posterior mandible supported by either freestanding implants at the first premolar and first molar sites or by the natural first premolar connected to an implant at the first molar site (n = 20). Up to 12 months later, the authors reported no differences in terms of implant survival or marginal bone loss between groups.

It is well documented that survival rate of short implants is similar to that of standard implants in clinical practice.[22–24] Although many papers have validated the success of short implants, there is no study in the literature evaluating the performance of short implants when combined with a tooth to support an FPD. The aim of this controlled prospective clinical study was to evaluate and compare the success of three-unit FSISPs with standard-length (≥ 8 mm) and short-implant (< 8 mm) three-unit CTISPs in the posterior mandible. The null hypothesis of the study was that there would be no difference in terms of mechanical and biologic complications, marginal bone levels around the implants, and implant survival between groups.

## MATERIALS AND METHODS

The current study was performed between 2015 and 2022 in the Çukurova University Faculty of Dentistry and was approved by the Ethics Committee for Noninvasive Researches of Çukurova University Medical Faculty (dated June 3, 2015, and numbered 44/16). All patients who met the inclusion criteria were enrolled in the study, and written patient consent was obtained for each patient. The inclusion criteria were as follows:


**Fig 1** One of the customized film holders used in the study.

- No systemic disorders
- Unilateral or bilateral partial edentulism in the posterior mandible with either fully dentate maxilla or a combination of natural teeth and implant-supported FPDs
- At least 3 months of healing since after tooth extraction at the implant site
- Periodontally and endodontically healthy abutment tooth
- Good oral hygiene
- Smoking habit of less than 10 cigarettes per day (or not at all)
- Presence of at least 2 mm of keratinized gingiva at the implant site

A power analysis was conducted to determine the correct number of patients per group (effect size = 0.4, α = .05, power = 0.8; three groups total). According to the power analysis, 78 patients were recruited to the study (n = 26 per group).

Group 1 received SLA (sandblasted, large-grit, acid-etched) surface implants (NucleOSS, T4 Dental Implants; 3.8- to 4.2-mm in diameter, 8- to 12-mm length) in the posterior mandible, replacing either the first premolar and first molar or second premolar and second molar to support the cement-retained three-unit FPD. This group served as the control group. Group 2 received one SLA surface implant (NucleOSS; 3.8- to 4.2-mm diameter, 8- to 12-mm length) to replace the mandibular first or second molar, and this was combined with the natural first or second premolar, respectively, to support the cement-retained three-unit FPD. Group 3 received one SLA surface implant (NucleOSS; 4.8-, 5.5-, or 6.2-mm diameter, 5- to 6-mm length) to replace the mandibular first or second molar, and this was combined with the natural first or second premolar, respectively, to support the cement-retained three-unit FPD.

Preoperative panoramic radiographic and CBCT examinations were performed on all patients to determine the amount of bone at the surgical site, the location of the mental foramen and the inferior alveolar canal, the bony support and periodontal condition of the abutment tooth, and the presence of any periapical lesions. Root length and form as well as any clinically undetectable pathology or bone abnormality were also considered.

## Surgical Procedures

Implant surgery was performed under local anesthesia. Once each implant was placed, a cover screw was inserted prior to immediate suturing of the flap with primary closure. Postoperatively, chlorhexidine mouthwash was prescribed twice daily for 7 days. The sutures were removed after 7 to 10 days. Stage-two surgery was performed after 2 months of healing, at which time healing abutments were placed.

## Prosthetic Procedures

Prosthetic procedures started 2 weeks after stage-two surgery. The abutment teeth to be combined with the implant were prepared with a guiding groove technique.[25] All preparations were made by full-time faculty members of the Department of Prosthetic Dentistry with a minimum of 15 years of experience. Provisional restorations (Dentalon Plus, Heraeus Kulzer) were fabricated directly after tooth preparation. After oral hygiene training, a follow-up appointment was scheduled at least 3 days later. Dental impressions of patients in Groups 2 and 3 were taken under local anesthesia. A 15% $AlCl_3$ retraction solution (Alustat, Cerkamed) was used for gingival retraction. Retraction cord was placed in the gingival sulcus, and this solution was then applied intraorally with the cord in place. After 2 minutes, the retraction cord was removed and an impression of the implant and tooth was taken with a closed tray one-step putty-wash impression technique using additional silicone-type elastomer (Elite HD, Zhermack). An occlusal record was also taken, and a follow-up appointment was scheduled for the metal substructure try-in.

An open tray impression technique was used for the impressions of implants in Group 1. Impression posts were attached to each other with autopolymerizing pattern resin (Duralay, GC), and an impression was taken with a one-step putty-wash technique using additional silicone-type elastomer (Elite HD).

Cast models were scanned with an extraoral scanner (3Series, Dental-Wings), and substructures were designed using CAD software (DWOS S.3.0, Dental-Wings). The minimum substructure thickness was 0.2 mm. All substructures were fabricated by a selective laser sintering (SLS) device (EOSINT M 270, EOS) using a cobalt-chromium alloy powder (Co-Cr SP2, EOS).

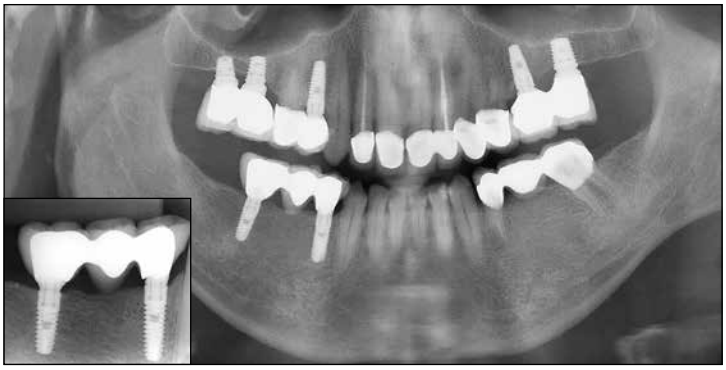

**Fig 2** Panoramic and periapical *(inset)* radiographs of a patient in Group 1 at the last follow-up visit.

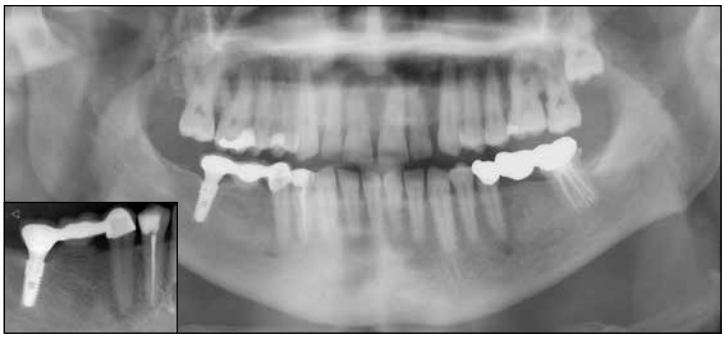

**Fig 3** Panoramic and periapical *(inset)* radiographs of a patient in Group 2 at the last follow-up visit.

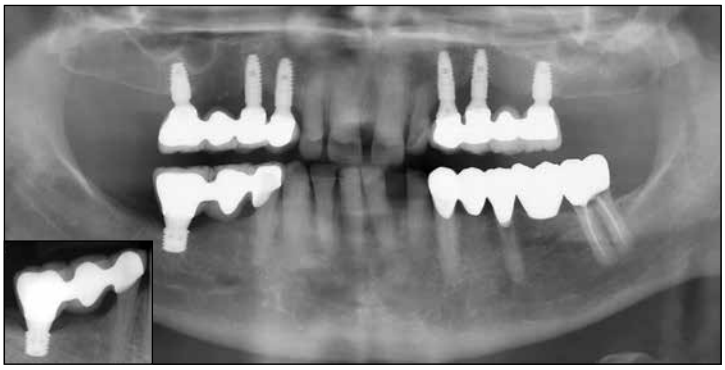

**Fig 4** Panoramic and periapical *(inset)* radiographs of a patient in Group 3 at the last follow-up visit.

All metal substructures were fully veneered with low-fusing dental porcelain (Super porcelain EX-3, DHXHO, Noritake) according to the manufacturer's instructions. During the ceramic try-in appointment, contacts with the adjacent teeth, occlusal contacts in centric relation, and excursive movements were adjusted according to the patient's natural occlusion. Marginal discrepancies were rechecked with a dental explorer. After glazing, the implant abutments were tightened to 35-Ncm torque prior to definitive cementation with polycarboxylate cement (Adhesor Carbofine, Spofa Dental).

## Radiographic Evaluation

The baseline for each implant was calculated at the time of definitive cementation of the FPD so that implant failures due to osseointegration problems were excluded. Periapical radiographs were taken with the long-cone parallel-beam technique with a film holder. A film holder was customized for each patient by indexing with provisional resin material (Dentalon Plus, Heraeus Kulzer). That same customized film holder was used when taking periapical radiography at every follow-up visit (Fig 1). Marginal bone resorption was evaluated on radiographs taken at the time of FPD delivery, 6 months after FPD delivery, and annually thereafter. The implant reference point was determined as the junction between the bevel and the threads. Marginal bone resorption was measured from the most coronal bone at this implant reference point to the implant contact on the mesial and distal aspects using Image J analysis software (Wayne Rasband, NIH). If the margin of the crestal bone was superior to the implant reference point, the value was considered as zero. The bone resorption value was recorded as the mean values of the distal and mesial changes from baseline for each implant (Figs 2 to 4). To avoid bias, crestal bone loss (CBL) was recorded and evaluated only on the distal implant in Group 1.

**Table 1 Dental Implant Distribution, Participant Age, and Follow-up Time**

| Group | Implants, n | Implant diameters/lengths, mm | Participant age | Follow-up time |
|---|---|---|---|---|
| Group 1 | 32 implants used in 16 patients | 2 implants: 3.8/8<br>8 implants: 3.8/10<br>3 implants: 3.8/12<br>2 implants: 4.2/8<br>12 implants: 4.2/10<br>5 implants: 4.2/12 | Mean: 56.8 y<br>Range: 37–73 y<br>Median: 60 y | Mean: 51.8 mo<br>Range: 39–72 mo<br>Median: 48 mo |
| Group 2 | 26 implants used in 26 patients | 4 implants: 3.8/8<br>7 implants: 3.8/10<br>2 implants: 4.2/8<br>10 implants: 4.2/10<br>3 implants: 4.2/12 | Mean: 53.19 y<br>Range: 41–66 y<br>Median: 54 y | Mean: 68.7 mo<br>Range: 35–72 mo<br>Median: 71 mo |
| Group 3 | 21 implants used in 21 patients | 1 implant: 4.8/5<br>4 implants: 4.8/6<br>3 implants: 5.5/5<br>9 implants: 5.5/6<br>1 implant: 6.2/5<br>3 implants: 6.2/6 | Mean: 55.7 y<br>Range: 42–68 y<br>Median: 53 y | Mean: 59.7 mo<br>Range: 27–72 mo<br>Median: 66 mo |

### Clinical Evaluation

At the time of FPD delivery and at all follow-up visits, the modified plaque index (MPI), bleeding index (BI), and sulcus depth of the abutment teeth were recorded.[26,27] To calculate MPI and BI, the clinician evaluated the plaque accumulation and bleeding around the selected teeth using a periodontal probe, giving scores to the buccal, lingual, mesial, and distal surfaces between 0 and 3 (0 represented no plaque accumulation and no bleeding on probing). The arithmetic means of the measurements yielded the average MPI and BI scores for that tooth. The average of all selected teeth in the patient's mouth provided the patient's average for MPI and BI for each visit. The average of all patients' MPI and BI provided the mean MPI and mean BI of each group for each follow-up time. Sulcus depth of the abutment tooth was measured with a periodontal probe on the mesial, distal, buccal, and lingual surfaces. The arithmetic mean of the measurements from all surfaces represented the sulcus depth of that abutment tooth on that follow-up. Abutment tooth intrusions, cementation failure of the restoration, porcelain chipping/delamination, framework fracture, abutment screw loosening, abutment and abutment screw fracture, and implant fracture were also recorded as complications.

At the end of the study, 63 out of 78 patients' data was collected (Group 1: 16 patients, Group 2: 26 patients, Group 3: 21 patients). Follow up of 15 patients was not completed (5 died, 3 moved to a different city, and 7 dropped out due to COVID-19 concerns). The study was registered to the U.S. National Institutes of Health Clinical Trials with registration number NCT05712031.

### Statistical Evaluation

Means and standard deviations of all evaluated parameters were calculated. Two-way ANOVA (independent factors: group and follow-up time point) followed by either Tukey HSD test (if variances were equal) or Dunnett T3 test (for unequal variances) were used ($\alpha = .05$).

## RESULTS

The number of dental implants placed, length and diameter of implants placed, mean and median age of patients, and mean and median follow-up times according to groups are presented in Table 1.

The mean values of MPI, BI, and CBL are presented in Table 2. Descriptive statistics of MPI, BI, and CBL measurements according to follow-up times are presented in Fig 5 and Table 3. The mean MPI of Group 1 was statistically significantly different than both Group 2 ($P = .001$) and Group 3 ($P = .008$). However, no difference was observed between Groups 2 and 3 ($P = .830$). No statistically significant difference was observed when the mean BI of Group 2 was compared with that of Group 3 ($P = .0607$) and Group 1 ($P = .151$). The mean CBL of Group 3 was statistically significantly different than both Group 1 ($P = .047$) and Group 2 ($P < .001$). However, no significant difference was observed between Groups 1 and 2 ($P = .604$). The mean abutment tooth sulcus depths according to follow-up time are presented in Fig 5. The mean abutment tooth sulcus depth was 1.11 ± 0.31 mm for Group 2 and 1.20 ± 0.46 mm for Group 3.

During the follow-up period, one patient in Group 1 had ceramic chipping, which was restored with intraoral polishing. However, in Group 2, ceramic chipping restored with intraoral polishing was observed in two patients, cementation failure was observed in two patients, and gingival recession with hypersensitivity was seen in two patients. Fabrication of a new restoration due to ceramic fracture was also necessary in one patient in Group 2, and one patient also needed root

canal treatment of the abutment tooth due to pulpitis. In Group 3, gingival recession with hypersensitivity was observed in one patient, gingival recession without hypersensitivity was seen in one patient, and implant removal due to loss of osseointegration during the second year of function was necessary for one patient.

**Table 2 Mean ± SD of Studied Parameters**

| Group | Modified Plaque Index | Bleeding index | Crestal bone loss, mm |
|---|---|---|---|
| Group 1 | 0.06 ± 0.17a | 0.04 ± 0.22a | 0.259 ± 0.05a |
| Group 2 | 0.18 ± 0.32b | 0.11 ± 0.34a,b | 0.03 ± 0.03a |
| Group 3 | 0.17 ± 0.30b | 0.14 ± 0.36b | 0.11 ± 0.03b |

Different lowercase letters represent a statistically significant difference ($P \leq .05$).

## DISCUSSION

The results of the current study failed to reject the null hypothesis that there would be no difference in terms of mechanical and biologic complications, marginal bone level around the implant, and implant survival between FSISP, short implant/tooth-supported FPDs, and standard implant/tooth-supported FPDs.

When combining a tooth and implant for FPD support, the prosthetic connection type (whether rigid or nonrigid) needs to be considered. While there are in vitro studies encouraging the use of nonrigid prosthetic connections in CTISPs,[28,29] papers including clinical studies correlate this type of prosthetic connection with abutment tooth intrusion.[5,8,30] Thus, a rigid prosthetic connection was preferred in this study, and FPDs were permanently cemented onto the abutments. The results of the current study support the results of the previously reported clinical studies, because no abutment tooth intrusion was observed in either of the experimental groups.

Another critical question was the type of the implant-abutment connection. Da Silva et al[31] and Chee and Mordohai[11] suggest using external hexagonal

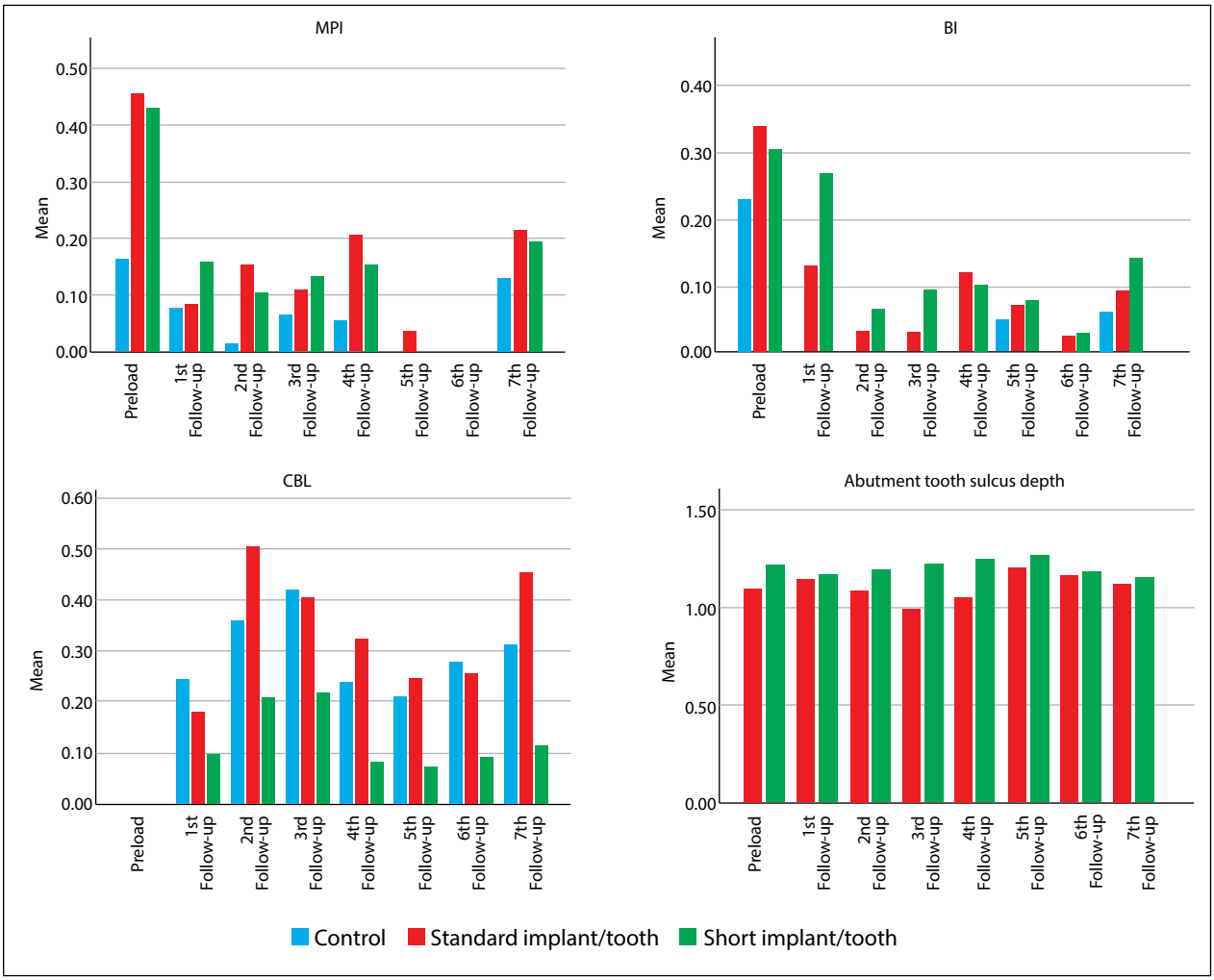


Fig 5 Bar graphs of mean MPI, BI, CBL, and abutment tooth sulcus depth by time point and group.

**Table 3 Descriptive Statistics of Mean CBL, MPI, and BI**

| Time point | Group | CBL, mm | MPI | BI |
|---|---|---|---|---|
| Preload | Control | 0.0000 | 0.1637 ± 0.23 | 0.2331 ± .052 |
| | Standard implant/tooth | 0.0000 | 0.4585 ± 0.42 | 0.3385 ± 0.66 |
| | Short implant/tooth | 0.0000 | 0.4314 ± 0.42 | 0.3048 ± 0.61 |
| | Total | 0.0000 | 0.3746 ± 0.40 | 0.3005 ± 0.60 |
| First follow-up | Control | 0.2450 ± 0.26 | 0.0769 ± 0.18 | 0.0000 ± 0.00 |
| | Standard implant/tooth | 0.1808 ± 0.32 | 0.0858 ± 0.18 | 0.1304 ± 0.49 |
| | Short implant/tooth | 0.0995 ± 0.16 | 0.1605 ± 0.25 | 0.2695 ± 0.51 |
| | Total | 0.1700 ± 0.26 | 0.1084 ± 0.20 | 0.1439 ± 0.40 |
| Second follow-up | Control | 0.3608 ± 0.60 | 0.0125 ± 0.03 | 0.0000 ± 0.00 |
| | Standard implant/tooth | 0.5065 ± 0.62 | 0.1552 ± 0.33 | 0.0320 ± 0.08 |
| | Short implant/tooth | 0.2060 ± 0.49 | 0.1040 ± 0.20 | 0.0667 ± 0.21 |
| | Total | 0.3654 ± 0.58 | 0.1010 ± 0.24 | 0.0355 ± 0.13 |
| Third follow-up | Control | 0.4213 ± 0.49 | 0.0643 ± 0.14 | 0.0000 ± 0.00 |
| | Standard implant/tooth | 0.4040 ± 0.60 | 0.1088 ± 0.29 | 0.0310 ± 0.14 |
| | Short implant/tooth | 0.2189 ± 0.54 | 0.1343 ± 0.22 | 0.0928 ± 0.25 |
| | Total | 0.3390 ± 0.56 | 0.1029 ± 0.23 | 0.0422 ± 0.16 |
| Fourth follow-up | Control | 0.2400 ± 0.16 | 0.0554 ± 0.19 | 0.0000 ± 0.00 |
| | Standard implant/tooth | 0.3243 ± 0.45 | 0.2058 ± 0.34 | 0.1208 ± 0.32 |
| | Short implant/tooth | 0.0813 ± 0.15 | 0.1538 ± 0.42 | 0.1059 ± 0.24 |
| | Total | 0.2255 ± 0.35 | 0.1473 ± 0.33 | 0.0825 ± 0.25 |
| Fifth follow-up | Control | 0.2100 ± 0.18 | 0.0000 ± 0.00 | 0.0500 ± 0.20 |
| | Standard implant/tooth | 0.2472 ± 0.49 | 0.0357 ± 0.13 | 0.0714 ± 0.23 |
| | Short implant/tooth | 0.0727 ± 0.12 | 0.0000 ± 0.00 | 0.0813 ± 0.22 |
| | Total | 0.1753 ± 0.34 | 0.0135 ± 0.08 | 0.0679 ± 0.22 |
| Sixth follow-up | Control | 0.2800 ± 0.17 | 0.0000 ± 0.00 | 0.0000 ± 0.00 |
| | Standard implant/tooth | 0.2565 ± 0.50 | 0.0000 ± 0.00 | 0.0250 ± 0.11 |
| | Short implant/tooth | 0.0907 ± 0.16 | 0.0000 ± 0.00 | 0.0313 ± 0.12 |
| | Total | 0.1924 ± 0.36 | 0.0000 ± 0.00 | 0.0192 ± 0.09 |
| Seventh follow-up | Control | 0.3137 ± 0.41 | 0.1300 ± 0.25 | 0.0625 ± 0.25 |
| | Standard implant/tooth | 0.4573 ± 0.69 | 0.2164 ± 0.29 | 0.0935 ± 0.21 |
| | Short implant/tooth | 0.1155 ± 0.16 | 0.1953 ± 0.27 | 0.1430 ± 0.28 |
| | Total | 0.3100 ± 0.52 | 0.1867 ± 0.27 | 0.1015 ± 0.24 |
| Total | Control | 0.2449 ± 0.36 | 0.0674 ± 0.17 | 0.0432 ± 0.22 |
| | Standard implant/tooth | 0.2965 ± 0.52 | 0.1822 ± 0.32 | 0.1109 ± 0.34 |
| | Short implant/tooth | 0.1120 ± 0.29 | 0.1713 ± 0.30 | 0.1439 ± 0.36 |
| | Total | 0.2208 ± 0.42 | 0.1463 ± 0.28 | 0.1029 ± 0.32 |

(hex) implants in CTISPs. The authors claim that higher screw flexibility in external hex implants compensate for the movement difference between teeth and implants. However, an internal hex implant-abutment connection offers more prosthetic stability, thus reducing the risk of prosthetic and biologic complications.[3] Moreover, there is a general tendency to use internal hex implant systems among dentists, which is why this type of implant system was used in the current study. No complications that can be associated with implant-abutment connection (eg, screw loosening, implant fracture, implant abutment fracture, or abutment screw fracture) were observed in any of the groups in the current study.

This study was planned to include one tooth with one pontic and one implant, and the implant was

always distal to the abutment tooth. Previous studies report more complications when an abutment tooth with root canal treatment is combined with dental implants to support an FPD.[17,32] However, controversial results have been reported about the periodontal condition of the tooth to be combined with implants. While Kindberg et al[33] reported excellent long-term results when periodontally sound teeth and implants are splinted together, Guarnieri and Ippoliti[15] and Cordaro et al[30] claim that teeth with reduced periodontal support can be connected to an implant to support an FPD following supporting therapy. To prevent bias concerning complications, in the current study only intact abutment teeth were combined with implants.

During the 6th ITI Consensus Conference, "short dental implants" were defined as those less than 6 mm in length.[34] However, there was no consensus about the diameter. Dental implant manufacturers generally manufacture short dental implants by simply shortening the standard-length implants. In the current study in Group 3, however, the short dental implants were specifically designed with lengths less than 8 mm but wider diameter and larger thread depth than standard dental implants (Fig 6). It is well known that increasing the diameter and thread depth of dental implants is effective in reducing stress on both the surrounding bone and the restoration.[35–37] Moreover, larger implant diameter allows the manufacturer to fabricate an abutment hex and abutment screw that is thicker than that for standard implants. This establishes dental implants with sufficient wall thickness to safely resist chewing forces. It can be speculated that due to the abovementioned advantages of short dental implants, fewer complications in the restoration and less marginal bone resorption was observed in Group 3 compared to Group 2. Many of the studies focusing on CTISPs reported similar mechanical and biologic complications compared to FSISPs.[18,20] CTISPs show slightly higher complication rates compared to FSISPs only in a limited number of studies. However, the authors of those studies still justify the use of CTISPs if needed, due to high survival rates.[18,20] The results of the current study are in accordance with these previous studies. However, our results encourage the combination of short dental implants with natural teeth to support FPDs. The mean follow-up period for Group 3 was close to 6 years, which is considered mid-term success.[38] It can therefore be concluded that combining a short dental implant with a tooth in the posterior mandible is a viable treatment method.

It is recommended to use customized film holders when following changes in CBL around dental implants using the parallel technique for periapical radiographs. Customized film holders can help ensure that the radiographic images are properly positioned and aligned, leading to more accurate measurements of the bone-level changes. In the current study, standardization of periapical radiographs was achieved by an indexed film holder with a ring positioner and a beam-guiding rod to allow parallelization between the x-ray tube and the film. This film holder is also designed to accurately position the x-ray sensor, ensuring the parallelism between the sensor and the long axis of the tooth. Distortion and magnification errors were thereby reduced, and accurate radiographs were taken.

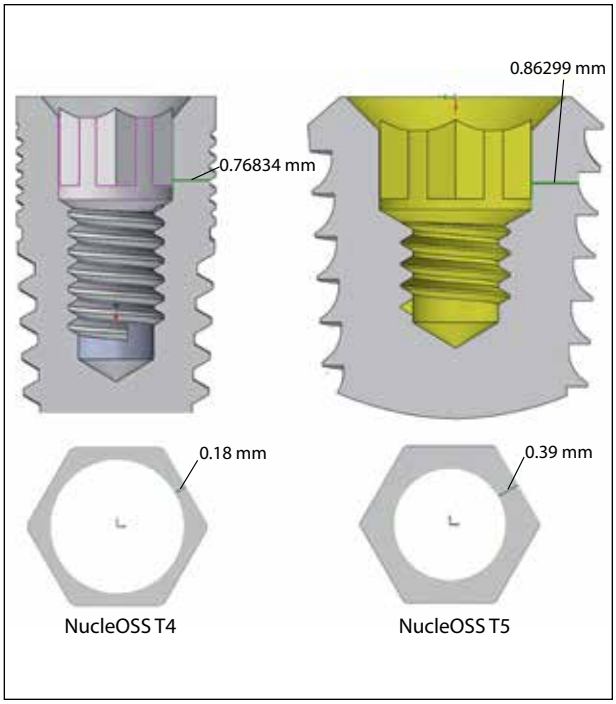


**Fig 6** Sagittal views of NucleOSS T4 and NucleOSS T5 dental implants and frontal views of their abutment hex.

To avoid any bias, the study design included only patients with partial edentulism in the posterior mandible and restorations with only one pontic. This can be regarded as the primary limitation of the current study. However, further clinical studies can be planned for FPDs with multiple pontics and/or in the anterior region with increased follow-up time of at least 10 years.

## CONCLUSIONS

Based on the results and within the limitations of the current study, FSISPs must be the primary treatment choice for patients with a partially edentulous posterior mandible. Nonetheless, CITSPs are a predictable treatment choice in the posterior mandible, and short implants are more predictable with this modality than standard-length implants.

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