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Implant-Supported Three-Unit Fixed Dental Prosthesis Using Coded Healing Abutments and Fabricated Using a Digital Workflow: A 1-Year Prospective Case Series Study

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Purpose: To test the applicability of coded healing abutments, intraoral scanners, and monolithic zirconia for the fabrication of three-unit fixed dental prostheses (FDPs) on two dental implants. **Materials and Methods:** Patients with three missing teeth in the posterior region of either the maxilla or mandible received two dental implants. After healing, coded healing abutments were placed. Full-arch intraoral scans were made to produce individual titanium abutments and a three-unit FDP. Peri-implant tissues were assessed 2 weeks after placement of the FDP and again after 1 year. Patient-reported outcome measures were registered prior to treatment and after 1 year. The quality of the FDPs was assessed using modified United States Public Health Service criteria after 1 year of service. **Results:** A total of 54 patients were treated with 60 restorations, and 51 patients with 56 restorations were available at the 1-year follow-up. Implant survival was 99.1%, and prosthesis survival was 100%. The peri-implant tissues remained healthy, and patient satisfaction was high. However, the USPHS evaluation showed that some prostheses exhibited fit or color issues that needed to be addressed, although most were rated as successful (80.4%). **Conclusion:** The use of coded healing abutments and intraoral scanners to produce full-zirconia three-unit FDPs on two dental implants proved to be a feasible technique, with promising objective and subjective results. However, technical challenges still impacted the treatment results, resulting in a number of restorations having clinical or radiographic marginal gaps or reduced color match. *Int J Prosthodont* 2020;33:609–619. doi: 10.11607/ijp.6707

Implant-supported restorations are now considered to be an established treatment modality for partial edentulism. Advances in materials and procedures for both implant surgery and prosthetics have broadened the scope of the indications and resulted in high survival and success rates for both the implants and the implant-retained fixed dental prostheses (FDPs).^{1,2}

There are, however, still some reasons for patients to waive implant-supported FDP treatment. Some patients dread the extent of the surgical and prosthodontic treatment, especially when multiple implants are planned. Others consider the treatment too expensive. It can thus be expected that a treatment procedure that is both less invasive and offered at reasonable costs, while maintaining a favorable treatment outcome, will be adopted by patients more easily.

When three adjacent teeth are missing in the posterior region, the first restorative choice for many clinicians is the use of three separate crowns retained by three separate implants.³ By eliminating the need for an additional implant, both the financial and

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surgical impacts of the treatment are reduced for most patients; however, since the costs of retreatment in the event of an implant loss will be higher for the patients affected, high implant survival is paramount. A recent systematic review found implant survival in three-unit posterior restorations to be 98.7% annually. Therefore, while there are a number of good reasons to use single-implant restorations, it has been established that the use of two implants to support a three-unit prosthesis is a feasible alternative, with survival and success rates comparable to the same treatment with two natural teeth as abutments.⁴

Another way to further reduce the impact of prosthetic treatment is to simplify it. It has been established that patients prefer a digital impression technique over a conventional impression tray.^{5,6} A digital workflow promises to offer restorations with optimal strength and esthetics, minimal effort from the clinician and the patient,^{7,8} and higher cost-effectiveness compared to conventional impression techniques.⁹ Simplifying the treatment might also increase the number of clinicians willing to perform implant-supported prosthodontics, further increasing availability to patients.

One specific implant system proposed to simplify dental implant treatment is the use of coded healing abutments. These can be placed by the surgeon at either the first or second stage of implant surgery, depending on the case and operator preferences. The prosthodontist does not need to remove these abutments for impression-taking, either digital or analog, because they are coded in a way that identifies both the diameter and height of the abutment, as well as the position and platform of the implant. After checking the proper seating and screw tightening of the abutment, the impression can be made, and the patient can leave immediately after it is finished.^{10–12} Because there is evidence that repeated abutment removal can result in increased peri-implant bone loss, manipulating the abutment and the surrounding gingiva only when placing the final restoration might be beneficial.^{13,14}

The use of zirconia is one of the more recent developments in the field of dental restorations. Due to the nature of this material, it can only be processed in a CAD/CAM workflow. The material offers very high strength, resulting in fewer complications. Previously, zirconia could only be used as a framework, which needed to be finished by adding a veneer. However, following recent advances in the material, it is possible to fabricate monolithic zirconia restorations. These can be offered at a low cost, especially when compared to labor-intensive and therefore costly alternatives, such as veneered metal or ceramic substructures.¹⁵

When considering the survival and success of FDP treatment, some of the most reported reasons for failure are chipping of the veneering material and fracture of

the framework. Addressing these issues is key to offering affordable and reliable implant prosthodontics. The use of monolithic zirconia restorations is a possible answer, as it eliminates the need for veneering material, allowing for a restoration of optimal thickness by using a material that is potentially strong enough to survive the more extreme chewing forces.^{16–18}

Full-scale outcome measures—including implant survival, restoration survival, marginal bone level changes, prosthesis success, condition of the peri-implant mucosa, patient satisfaction, and evaluation of technical procedures—of a three-unit zirconia restoration supported by two implants have never been described.⁴ Prospective clinical studies on the use of coded healing abutments combined with intraoral scanners to produce CAD/CAM multi-unit implant-retained FDPs have not yet been published to the present authors' knowledge, although the feasibility has been proven *in vitro*.^{19–21} Therefore, the aim of this prospective case series study was to assess the clinical performance of three-unit monolithic zirconia implant-retained prostheses with a central pontic, produced using a digital workflow, over the course of a 1-year follow-up period.

MATERIALS AND METHODS

Inclusion Criteria

This prospective case series study considered all consecutive patients over a 3-year inclusion period eligible to participate if they had at least three adjacent missing teeth in the posterior region of the mandible or maxilla. All patients were screened using clinical and radiographic examinations to determine if they met the following inclusion criteria:

- Over 18 years of age and capable of understanding and giving informed consent
- Sufficient horizontal and vertical space to place a three-unit FDP
- Sufficient bone levels at the proposed implant sites to place implants with a length of at least 8.5 mm and a width of 4 mm
- Presence of natural antagonistic teeth or an opposing prosthesis

Having any of the following was regarded as a criterion for exclusion from the study:

- Uncontrolled pathologic processes in the oral cavity
- Known or suspected current malignancy
- History of radiation therapy in the head and neck region
- History of chemotherapy within 5 years prior to surgery
- Systemic or local disease, condition, or medication that could compromise postoperative healing and/or osseointegration

- Smoking (with intention to continue)
- Regular alcohol and/or drug use

After consulting the Medical Ethical Committee of the University Medical Center Groningen, The Netherlands, it was determined that this case series study was not subject to the Medical Research Involving Human Subjects Act (Number M13.145175). The patients fulfilling all of the inclusion criteria (and none of the exclusion criteria) were informed orally and in writing about the study and signed the informed consent form. The patients were treated in the University Medical Center Groningen.

Surgical Procedures

One day before implant placement, the patients began rinsing with a chlorhexidine mouthrinse (Corsodyl, GlaxoSmithKline) for 1 minute twice daily for 2 weeks. One hour before surgery, the patients took oral antibiotics (3 g amoxicillin or 600 mg clindamycin). Surgery was performed under local anesthesia. Two platform-switched, titanium-screw implants (T3 Tapered with DCD surface, Zimmer Biomet Dental) with a diameter of 4.0 mm and a length of 8.5 to 15 mm were placed according to the appropriate surgical procedures instructed by the manufacturer. The implant site was prepared using a surgical template. Implant length was determined based on available bone volume. The implants were placed slightly below the crestal bone level according to the manufacturer's instructions. The surgical flap was closed using slowly resorbable sutures (Vicryl, Johnson & Johnson).

Two weeks after implant placement, the residual stitches were removed. After 3 months, the implants were uncovered. A two-piece coded healing abutment (BellaTek Encode, Zimmer Biomet) was placed, and implant stability was examined using two blunt-ended instruments.²² The diameter of the abutment (4 mm, with a 3.4-mm platform) was determined by the implant system, and the abutment height (either 3, 4, or 6 mm) was chosen preoperatively based on gingival thickness to ensure sufficient supragingival visibility (at least 1 mm at the lowest point) of the coded healing abutment. The patient was given oral hygiene instructions to clean the healing abutments.

Prosthetic Procedures

Fabrication of the prosthesis started 2 weeks after the second surgical stage. The correct seating and screw tightening of the coded healing abutments were tested. A disposable lip and cheek retractor was placed to help with tissue management (OptraGate, Ivoclar Vivadent), and a moldable saliva ejector (Hygoformic U, Orsing) was used to keep the tongue aside and eject excess fluids. Before scanning, the teeth and abutments were dusted with a titanium-oxide powder (High-Resolution

Scanning Spray, 3M ESPE). An intraoral scan was made using an intraoral scanner (Lava C.O.S. [software version 3.0.2] or Lava True Definition [software version 5.1.1], 3M ESPE). Full-arch intraoral scans were made starting with the maxilla, then the mandible, and finally the left and right buccal regions to establish the occlusion. Scans were performed in accordance with the manufacturer's instructions until sufficient data were captured: without holes in the image of the abutments and surrounding regions, including the contact points, and with solid information on the occlusion. Any warning or error generated by the scanner software was resolved before a scan was finalized. Calibration of the scanner was performed regularly per manufacturer instructions.

The scan data, along with a digital prescription, were sent to a design center (Biomet 3i, Valencia, Spain) using the cloud-based storage and work order system incorporated in the scanner software. The abutments were designed based on the specifications and preferences provided by the dentist. After the dentist reviewed the digital design file, the abutments were produced from custom-milled titanium (BellaTek Encode Patient Specific Abutment, Zimmer Biomet Dental) and delivered to the prosthodontist's dental laboratory.

The digital design of the abutments was included with the digital impressions and uploaded to the cloud-based order system so that the dental laboratory could download the abutment design and digitally design and manufacture the three-unit FDP.

The FDP was milled full-contour from an yttria-stabilized tetragonal zirconia polycrystal (Y-TZP), full-zirconia material (Lava Plus High Translucency, 3M ESPE). Shading was done before sintering per manufacturer recommendations using the dyeing liquids for this specific zirconia system. After sintering, the prosthesis and abutments were checked for fit, and final corrections were performed. The surface of the prosthesis was thoroughly polished, and a final glaze was applied. A full-arch stereolithographic model, whereby the abutments were printed in situ, was used to check the final product.

On returning to have the final restoration fitted, the coded healing abutments were removed. After testing the abutments and FDP to verify adequate fit and proximal contact points, the abutments were seated on the implants using the connection screws provided by the manufacturer (Certain, Gold-Tite Screw, Zimmer Biomet Dental) at the recommended torque value (20 Ncm) using the torque wrench provided by the implant manufacturer.

The screw access holes were sealed with a cotton pellet, and, subsequently, the FDP was cemented using a glass-ionomer-based cement (Fuji I, GC Europe). While hardening, the excess cement was removed using dental floss and a dental probe. Static and dynamic occlusion were checked meticulously, probing pocket depths were

noted for future reference, and an intraoral radiograph was taken to check the fit of the FDP and the presence of excess cement, as well as to provide an initial reference of the bone levels surrounding the implants. The patient was instructed in hygiene procedures to maintain the implants and prosthesis, and recalls were scheduled for 2 weeks and 1 year following FDP placement.

Clinical Evaluation

Clinical examinations of the peri-implant mucosa condition were performed 2 weeks and 1 year after placement of the final restoration, by the same trained dentist, using the following criteria:

- Assessment of plaque accumulation with the modified Plaque Index²³
- Assessment of bleeding with the modified Sulcus Index²³
- Assessment of peri-implant inflammation with the Gingival Index²⁴
- Presence of dental calculus
- Probing pocket depth (measured to the nearest millimeter using a manual periodontal probe)

Quality of the FDP

The quality of the restoration was assessed according to modified United States Public Health Service (USPHS) criteria.^{25,26} Framework fracture, veneer fracture, loosening of the restoration (cement and/or screw), occlusal wear, clinical marginal adaptation, anatomical form, restoration color, radiographic marginal adaptation, and patient satisfaction were evaluated as items defining the quality of the restoration. A restoration was considered to be successful if all aspects scored only in the Alpha or Bravo categories. Restorations with one or more Charlie scores were considered unsuccessful, but surviving. Restorations scoring Delta were considered a failure, and thus also unsuccessful. Any fracturing or loosening reported during the observation period was also included in the evaluation.

Radiographic Evaluation

Intraoral radiographs were taken at 2 weeks and 1 year after FDP placement using a parallel technique to evaluate the peri-implant bone levels. A dentist (C.P.) trained to use specially designed computer software performed and analyzed the linear measurements on the digital radiographs. Calibration was carried out in the horizontal and vertical planes for each radiograph using the known dimensions of the implants to ensure correct measurement. Peri-implant bone level changes were determined by measuring, both mesially and distally, the distance from the implant reference point (the junction between the implant and the abutment) to the level of the margin of the crestal bone. For each implant, bone loss was registered as the largest (ie, worst) value (at either the distal

or mesial implant) of the change between 2 weeks and 1 year after restoration placement. A statistical analysis of the difference in bone loss between the mesial and distal implants was performed.

Patient Satisfaction

Patient satisfaction was assessed before surgery and 1 year after restoration placement with the questionnaire used by Telleman et al.²⁷ The patients were asked to respond to a series of statements regarding their dental situation, feelings, esthetics, and function, with answers on a 5-point rating scale ranging from “very dissatisfied” or “not in agreement” (1) to “very satisfied” or “in agreement” (5). Furthermore, patients were asked to rate overall satisfaction concerning their dental situation at the time of enrollment and at the 1-year evaluation on a scale from 1 to 10, where 10 was the highest satisfaction score.

Statistical Analyses

For the clinical and radiographic parameters, the worst scores per implant were used for data analysis and were presented as frequency distributions. The differences in bone-level change between the mesial and distal implants and differences in patient satisfaction between pretreatment and the 1-year follow-up were tested with Wilcoxon signed-rank test. Analyses were performed with IBM SPSS Statistics 23.0. A significance level of .05 was chosen for all tests.

RESULTS

Over the course of the 3-year inclusion period, all 55 consecutive patients eligible for participation on the basis of the inclusion and exclusion criteria agreed to participate (31 women, 24 men; mean age at implant placement 60.5 years, range 35 to 78 years). Of these patients, 6 sought replacement in both the left and right sides of the mouth; therefore, 61 treatments were planned. In three instances, a patient was included again after being previously treated in this same study in another region of the mouth, with 1.5 years between the respective implant placement surgeries.

One patient was excluded during the surgical phase because of a protocol violation (a different brand of implant was placed preoperatively due to absence of the required smaller diameter implant). This patient was treated successfully outside the present study. Therefore, 60 cases in 54 patients remained for evaluation.

The 120 implants were placed by three experienced surgeons (treating 37 [G.P.], 13, and 10 cases each). During the surgical phase, no major complications occurred and wound healing was uneventful, except in two cases where the wound became infected. Both cases were treated successfully with 1 week of antibiotics and



Fig 1 Intraoral scan of a coded healing abutment.



Fig 2 Full-contour zirconia FDP with two supporting implants and a central pontic in the maxillary right posterior region.

chlorhexidine rinse. In some cases ($n = 9$), loosening of the healing abutment screw was detected at the next appointment or reported by the patient; in 2 of these cases, this resulted in inflammation of the surrounding gingiva, which resolved after retightening of the screw.

One early implant failure occurred: One mesial implant (maxillary left second premolar region) was removed during abutment placement due to lack of osseointegration. In this case, another implant was placed after a healing period, and the patient was successfully treated as planned using the study protocol, but outside the study.

The prosthetic phase of the remaining 59 cases (53 patients) was performed by one experienced dentist (C.P.). The first 28 consecutive cases were scanned with the Lava C.O.S. system, and the next 31 cases were scanned with the newer Lava TrueDefinition system (Fig 1); this was done out of necessity, as the support for the C.O.S. system was withdrawn by the manufacturer during the course of the study. Two weeks after placement, all 59 FDPs (33 in the maxilla, 26 in the mandible) were available for the first evaluation (Fig 2). Sixteen cases had a distal tooth present (all natural teeth), while in the remaining 43 cases, the FDP served as the most distal occlusal unit.

Two patients were unavailable for the 1-year follow-up: One patient with two FDPs had a rapidly declining health status, and one patient had a temporary medical condition. It was reported that these three FDPs were still in function. All 51 other patients, with 56 restorations, attended the 1-year follow-up.

The one implant failure before loading meant that implant survival was 99.1% at 1 year (113 out of 114 placed implants were in situ). Prosthesis survival was 100% at the 1-year follow-up; all 56 FDPs were still in function at the time of evaluation.

The mean scores of the indices for plaque, calculus, gingiva, and bleeding were mostly low (Table 1). The mean pocket probing depth at the 1-year follow-up evaluation was 3.8 ± 1.3 mm. One patient, who had

received FDPs during two different treatments in two different regions, developed a peri-implant infection in both regions, leading to excessive bone loss and a larger probing pocket depth with bleeding, which accounted for most of the detrimental clinical indices. This patient was included based on the estimate that she was healthy enough for the treatment, but was later found to be undergoing immunosuppressive treatment for an aggravated nonrelated systemic disease, to which the impaired healing could be attributed.

The mean radiographic bone loss between the 2-week and 1-year follow-ups was 0.32 ± 0.44 mm at the mesial implant and $0.26 \text{ mm} \pm 0.52$ mm at the distal implant supporting the FDP, with no significant difference between the mesial and distal implants ($P = .441$) (Table 2, Fig 3). The patient satisfaction ratings of the treatment are presented in Table 3. Overall satisfaction increased significantly over the 1-year interval ($P < .001$). The patients felt less ashamed after the missing teeth were replaced, their chewing ability had increased, and they did not hesitate to use the prosthesis. A small number of patients were not satisfied with either the shape or color of the FDP.

At the peri-implant level, the mean radiographic bone loss between 2 weeks after loading and the 1-year follow-up was $0.32 \text{ mm} (\pm 0.44)$ at the mesial implant and $0.26 \text{ mm} (\pm 0.52)$ at the distal implant supporting the FDP. At the patient level, using the highest (ie, worst) value per patient, the mean radiographic bone loss was 0.47 ± 0.49 mm.

The success rate of the restorations, evaluated during the first year of service using the modified USPHS criteria (Table 4), was found to be 80.4% ($n = 45$). One or more items of the remaining 11 restorations (19.6%) scored in the Charlie category and were thus considered to be an unsuccessful treatment for the scope of this study, although all were still in service at the 1-year follow-up. The complications were mainly associated with technical

Table 1 Plaque, Calculus, Gingival, and Bleeding Scores and Probing Depth (mm) at 2 Weeks and 1 Year After Restoration Placement

	Mesial implant		Distal implant	
	2 wk (n = 59)	1 y (n = 56)	2 wk (n = 59)	1 y (n = 56)
Plaque Index (0–3)				
0	47 (79.7)	53 (94.6)	51 (86.4)	53 (94.6)
1	10 (16.9)	2 (3.6)	7 (11.9)	2 (3.6)
2	2 (3.4)	1 (1.8)	1 (1.7)	1 (1.8)
Calculus Index (0–1)				
0	59 (100)	56 (100)	59 (100)	56 (100)
Gingival Index (0–3)				
0	55 (93.2)	52 (92.9)	56 (94.9)	50 (89.3)
1	4 (6.8)	4 (7.1)	3 (5.1)	6 (10.7)
Bleeding Index (0–3)				
0	31 (52.5)	23 (41.1)	31 (52.5)	33 (58.9)
1	21 (35.6)	23 (41.1)	21 (35.6)	14 (25)
2	6 (10.2)	8 (14.3)	6 (10.2)	7 (12.5)
3	1 (1.7)	2 (3.6)	1 (1.7)	2 (3.6)
Mean (SD) probing depth, range	3.44 (1.22), 1–7	3.93 (1.22), 1–7	3.27 (1.19), 1–6	3.75 (1.28), 1–7

Data are reported as n (%) at the implant level unless otherwise indicated.

Table 2 Mean (SD) Values and Frequency Distribution of Marginal Bone Level Change (Highest [ie, Worst] Value per Implant) Between Loading and 1 Year of Function

	Mesial implant (n = 56)	Distal implant (n = 56)	Overall (n = 112)
Mean (SD) bone change, mm	−0.32 (0.44)	−0.26 (0.52)	−0.29 (0.48)
−3.0 to −2.5	–	1 (1.79)	1 (0.89)
−2.5 to −2.0	–	–	–
−2.0 to −1.5	2 (3.57)	–	2 (1.79)
−1.5 to −1.0	3 (5.36)	5 (8.93)	8 (7.14)
−1.0 to −0.5	10 (17.86)	8 (14.29)	18 (16.07)
−0.5 to 0.0	28 (50.00)	17 (30.36)	45 (40.18)
0.0 to 0.5	13 (23.21)	24 (42.86)	37 (33.04)
0.5 to 1.0	–	1 (1.79)	1 (0.89)

Data are reported as n (%) at the implant level unless otherwise indicated. Negative values indicate loss, and positive values indicate gain, in marginal bone level. The comparison of marginal bone level change between mesial and distal implants was nonsignificant ($P = .441$).

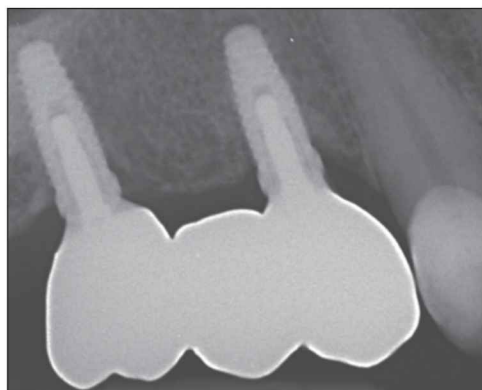
**Fig 3** Intraoral radiograph of an FDP restoration 1 year after placement.

Table 3 Patient Satisfaction Before Treatment (n = 60) and After 1 Year (n = 56) and Significant Differences Between the Time Points

	Before treatment, n (%)	1 y, n (%)	P value
Feelings			
Presence of shame	26 (43.3)	2 (3.6)	< .001
Self-confidence decreased	15 (25.0)	9 (15.0)	< .001
Visibility of partially edentulous region	27 (45.0)	2 (3.6)	< .001
Function			
Evade eating with the edentulous zone/implant	45 (75.0)	2 (3.6)	< .001
Ability to chew has decreased	53 (88.3)	3 (5.0)	< .001
Esthetics			
Not satisfied with the color of the crown	–	5 (8.3)	
Not satisfied with the form of the crown	–	3 (5.0)	
Overall satisfaction (0–10), mean ± SD (range)	5.1 ± 1.8 (1–10)	8.3 ± 1.0 (7–10)	< .001

aspects, including clinical and radiographic marginal adaptation (Fig 4) and color match.

DISCUSSION

When examining survival, the full-contour zirconia FDPs with two supporting implants and a central pontic in the posterior region showed an outstanding performance, with a 1-year survival rate of 100% paired with a 100% survival rate of the loaded implants. Although prosthesis success according to the USPHS criteria was high at 80.4%, some restorations exhibited complications such as loosening, a larger marginal gap, or color mismatch. Therefore, the process of using a coded healing abutment and an intraoral scanner to produce patient-specific abutments and a three-unit prosthesis proved to be a viable treatment option, but with room for improvement in prosthesis success. Nevertheless, all included patients were treated using the proposed workflow, and all prostheses survived the first year functionally, with high patient satisfaction.

FDP survival was high, which is in accordance with the findings from a recent systematic review on three-unit posterior FDPs by Pol et al,⁴ which reported an average annual failure rate of 2.6% after analyzing 765 implant-retained prostheses in 24 different studies. The review reported an average annual complication rate of 1.94%, with most complications due to loosening and chipping. It must be noted, however, that the included studies described prostheses made of a large variety of materials, including those more prone to chipping or fracture, and some included screw-retained restorations.

In the present study, three FDPs (5.1%) required repositioning after cement failure. Although this number is

higher than indicated in the literature, it can be explained by the fact that all FDPs in this study were cemented, whereas the previous review also included screw-retained restorations.⁴ Furthermore, in one instance, the abutments were found to be relatively low (1.5 to 3 mm), providing little retention for the type of nonadhesive cementation used. As expected with monolithic zirconia, no instances of chipping were observed, eliminating one of the most reported complications in implant-retained prosthetic treatment.

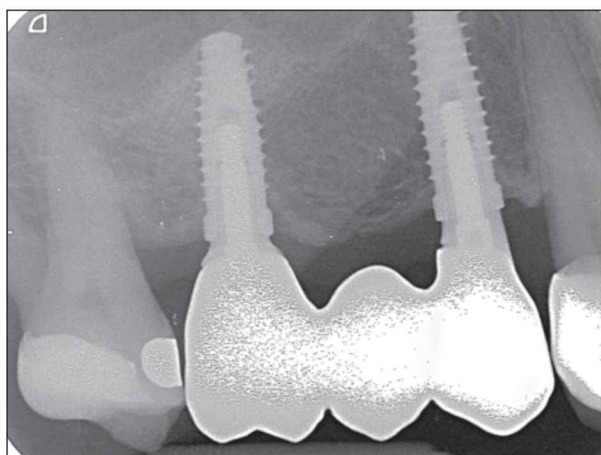
Clinical variables, measured as plaque, calculus, gingival, bleeding on probing, and pocket probing depth indices, were mainly low or very low, although a few patients showed an elevated plaque or bleeding index. The findings for mean bone loss were in agreement with a previous study using the same implant system for the replacement of single units,²⁷ which reported 0.50 ± 0.53 mm of bone loss after 1 year, indicating that there is no difference between the implants used to support an FDP vs single-unit replacements and splinted restorations in the authors' clinic.

Patient satisfaction was generally high. All patients reported a highly positive effect of the treatment on their oral function, which was affirmed by the fact that a number of patients asked to be included for an additional restoration during the first year of evaluations after inclusion had ended. In some cases, the patient declared that their self-confidence had not been enhanced by the placement of the prosthesis, but had also declared that their self-confidence had not suffered when the teeth were missing; so, logically, improvement was not expected.

The only negatively reported aspects of satisfaction were the color and form of the FDP. The first can be largely explained by the inability to produce optimal

Table 4 Evaluation of Survival and Success Criteria of the Restorations (n = 56) Based on Modified USPHS Criteria Over the First Year of Service

USPHS criteria	Alpha	Bravo	Charlie	Delta
Framework fracture	No fracture: 56 (100)	–	–	Fracture of framework: 0 (0)
Veneer fracture	No fracture: 56 (100)	Chipping, but polishing possible: 0 (0)	Chipping down to framework: 0 (0%)	New reconstruction is mandatory: 0 (0%)
Loosening of the restoration (cement and/or screw)	No loosening: 53 (94.6)	–	Loosening, but repositioning possible: 3 (5.4)	Repositioning not possible, new restoration needed: 0 (0)
Occlusal wear	No wear facets on restoration or opposing teeth: 56 (100)	Small wear facets (diameter < 2 mm) on restoration and/or opposing teeth: 0 (0)	Wear facets (diameter > 2 mm) on restoration and/or opposing teeth: 0 (0)	New reconstruction needed: 0 (0)
Marginal adaptation	Probe does not catch: 40 (71.4)	Probe catches slightly, but no gap detectable: 12 (21.4)	Gap with cement exposure: 4 (7.1)	New reconstruction needed: 0 (0)
Anatomical form	Ideal anatomical shape, good proximal contacts: 54 (96.4)	Slightly over- or undercontoured, weak proximal contacts: 2 (3.6)	Highly over- or undercontoured, open proximal contacts: 0 (0)	New reconstruction needed: 0 (0)
Restoration color	No mismatch in color shade between restoration and adjacent teeth: 31 (55.4)	Slight mismatch in color shade between restoration and adjacent teeth: 22 (39.3)	Great mismatch in color shade between restoration and adjacent teeth: 3 (5.4)	Gross disharmony in color shade between restoration and adjacent teeth, new reconstruction needed: 0 (0)
Radiographic assessment	No visible cementation gap: 23 (41.1)	Minor gap visible: 27 (48.2)	Major gap visible; new reconstruction not needed: 6 (10.7)	Major gap visible; new reconstruction needed: 0 (0)
Patient satisfaction	Very satisfied: 43 (76.8)	Moderately satisfied: 13 (23.2%)	Not satisfied; new reconstruction needed: 0 (0)	Not satisfied; new reconstruction needed: 0 (0)
Overall (worst value per FDP)	Success 9 (16.1)	Success 36 (64.3)	Survival: 11 (19.6)	Failure: 0 (0)

**Fig 4** Intraoral radiograph of an FDP with a minor gap visible between the prosthesis and the abutment 1 year after placement.

esthetic results with the particular type of full zirconia used, especially in more challenging situations. It would be recommended to use either another, more recent generation of translucent zirconia with better color rendition or more conventional prosthetics with a framework with fused porcelain. The patients' opinion on color was also affirmed by the lower scores for color match in the USPHS criteria as assessed by a dentist.

The main criticism from patients on the form about the restoration concerned the design of the pontic and interproximal spaces, which were designed to facilitate the use of interproximal cleaning devices and to bridge the difference in the emergence profile of the implants compared to the crown dimensions. Although explication did much to satisfy the patients, a few of them admitted to having expected a more natural tooth-like restoration.



The use of the Encode coded healing abutments, with the Lava C.O.S. and TrueDefinition intraoral scanners, proved to be a workable technique, producing usable FDPs on every account. The method, though, was not without limitations. The use of digital techniques certainly solves many problems, but also introduces new ones. On several ($n = 7$) occasions, the scan had to be redone after it was rejected. Although it is also not uncommon for conventional impressions to be rejected by the technician because of technical imperfections, the workflow used in this study introduced a unique possible defect: The main reason for rejection of scans was that, on closer inspection, the image of the abutments provided insufficient information on either the size or angulation of these abutments to be able to correctly ascertain the exact implant position. This can only be resolved by making another scan.

The premise of a scannable healing abutment has some inherent limitations. On one hand, the abutments need to be smooth and shiny to allow for healthy and clean peri-implant tissues during the healing phase, and preferably be low enough that they can be worn under a temporary removable prosthesis. On the other hand, they need to be the exact opposite for scanning, as they should be as high as possible to allow for accurate scanning of the insertion angle of the implant. Also, they should be anything but shiny and smooth: preferably multi-angular with sharp, defined edges and a highly profiled surface. In some instances, it was inevitable that the abutments had to be removed and replaced with a higher type just for scanning, which eliminated one of the possible benefits of the encoded abutment. The use of powder to matte the abutment surface before scanning was found to be inevitable—since this is an integral part of the workflow of the particular scanner that was used—and it proved to be a highly technique-sensitive part of the procedure, requiring training and experience.

The production workflow, from the perspective of a dental office, worked acceptably well. All abutments were produced according to plan, and all parts were delivered on time. All restorations could be placed, some after corrections, and were functional after 1 year. When taking the dental laboratory into consideration, there are several issues that need to be addressed, many of which might have to do with either the learning curve of the new techniques or the type of zirconia used in producing the restoration. For example, at first it proved difficult to produce the correct restoration shades, prompting quite a few remakes, as there is no other way to correct the color in monolithic zirconia restorations. Ample manual correction and polishing were necessary after sintering because of the difference in the desired marginal thickness compared to the minimal dimensions of the material before sintering. Moreover, the precision of fit of the abutments in the prosthesis was, in many instances,

too good to be clinically workable. Therefore, a slightly larger cementation space (0.12 mm) had to be designed to prevent adjustments having to be performed after sintering, which would be undesirable from the materials science aspect. Thus, CAD/CAM techniques do not eliminate the need for skilled dental technicians.

Clinically, slight adjustment of the contact points or occlusion was necessary in many instances to allow for placement of the restoration, requiring careful, time-consuming polishing of the zirconia surface to achieve the desired surface properties.

It has been previously established that the marginal accuracy of CAD/CAM frameworks can be similar to conventional lost-wax casting techniques.²⁸ Nonetheless, a worryingly high number of slight to medium marginal misfits (according to USPHS score) was observed in this study, as expressed in Table 4. Many of the smaller gaps were only visible on the radiographs. The larger gaps were all supragingival and thus considered to be of no influence on peri-implant health. The range of accuracy of intraoral scanners is comparable to conventional impression techniques.²⁹ Although the precision has proven to be high enough for single-unit prostheses, the fabrication of multi-unit restorations will require higher accuracy to ensure acceptable fit and optimal biomechanical function.³⁰

Various aspects of the workflow might contribute to the inaccuracy of fit. First, there is the aspect of the implant components, especially in multi-unit restorations with angled and individualized abutments.³¹ Inaccuracy in a digital workflow could originate either from the data capturing or the data processing.^{29,32} Intraoral scanners are known to struggle with precision in edentulous areas—when there is insufficient topographic information available, the scanner software struggles with combining the various images—an aspect that is unavoidable in this type of treatment.^{33,34} The rounded, shiny aspects of the scan abutments also provide limited guidance for the scanner software. Given the fact that the other parts of the procedure have proven to be accurate enough, it is suspected that the inaccuracy in marginal adaptation originates from the data acquisition phase. This should be subjected to further research into the development of new generations of intraoral scanners.

During execution of this study, the manufacturer withdrew support for the intraoral scanner used, resulting in the second half of the cases being treated with the next generation of intraoral scanner. As this was not foreseen, no data were recorded to compare the two scanners on factors such as time used for scanning and processing. Both scanners use the same type of imaging system and exhibited no significant difference in precision.²⁹

Although some aspects of the treatment and the prosthetic results could be developed and optimized further, the workflow proposed in this study delivered

a functional fixed restoration while minimizing the cost, surgical impact, and time required for prosthetic procedures. Eliminating an implant and replacing it with a central pontic can save on the costs of one implant, one abutment, and the corresponding treatment time requirements. The use of the coded healing abutment eliminated the chair time required to replace healing abutments with scan bodies and vice versa. The digital workflow minimized the number of appointments required and eliminated the use of conventional impression techniques, which patients reported as a benefit. Finally, the full zirconia material proved to be a feasible alternative to the more costly and time-consuming veneered alternatives. Therefore, implementing all of these steps could contribute to a more cost-effective and less time-consuming treatment, further lowering the threshold for patients to accept implant-supported restorations.

CONCLUSIONS

The digital fabrication of a three-unit FDP on two implants proved to be a viable treatment modality, with 100% survival of implants and prostheses after 1 year of clinical use, good clinical performance, and high patient satisfaction. The prosthesis success rate (80.4% after 1 year) was impeded by the insufficient color results of the full-zirconia restoration material used and by the occurrence of improper marginal adaptation, possibly originating from imperfections in the digital workflow. Thus, although a feasible treatment strategy, some aspects of the procedure still require a higher level of skill and dedication from all of the professionals involved to achieve clinically acceptable results.

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Literature Abstract

Do Speakers Fully Disclose Potential Conflicts of Interest in Oral and Maxillofacial Surgery?

Complete disclosure of conflicts of interest is critical to providing objective and ethical continuing education. The purpose of this study was to determine the accuracy of financial relationships disclosed by speakers at an annual oral and maxillofacial surgery conference. This retrospective cross-sectional study compared speakers' disclosures on the American Association of Oral and Maxillofacial Surgery Dental Implant Conference 2018 website to the payments reported on the Centers for Medicare and Medicaid Services Open Payments Database. The predictor variable was the number of companies reported by the speaker, and the outcome variable was the number of relevant companies discovered on the Open Payments Database. Other variables evaluated included the total dollar sum transferred and the type of speaker (oral and maxillofacial surgeon [OMS] vs non-OMS). Companies providing payments to speakers on the Open Payments Database were deemed relevant if they had provided goods or services relevant to dental implants. Descriptive statistics were computed, and Student *t* test was performed, with $P < .05$ considered to indicate statistical significance. A total of 43 speakers were included (32 OMS; 74.4%). It was found that 35 of the 43 speakers (81.4%) had received payments relating to dental implants on the Open Payments Database that had not been disclosed on the conference website. On average, the speakers disclosed 0.65 ± 1.04 companies; however, 2.51 ± 1.32 relevant companies per speaker were reported on the Open Payments Database ($P < .0001$). The OMS speakers disclosed 0.47 ± 0.95 companies on the conference site, but had 2.47 ± 1.32 companies reporting payments on the Open Payments Database ($P < .0001$). Non-OMS speakers disclosed 1.18 ± 1.17 companies, with 2.64 ± 1.36 companies listed on the Open Payments Database ($P = .0044$). Continuing education conferences offer an avenue for spreading knowledge; however, the objectivity of the information presented could be affected by undisclosed conflicts of interest. The results from the present study have demonstrated that most speakers at an annual oral and maxillofacial surgery conference have underreported payments from companies relevant to the conference topic.

Durrani I, Ji YD, Peacock ZS. *J Oral Maxillofac Surg* 2020;78:1669–1673. References: 12. Reprints: Z. Peacock, zpeacock@partners.org —Tony Pogrel, USA

Literature Abstract

Fifteen-year Outcome of Three-Unit Fixed Dental Prostheses Made from Monolithic Lithium Disilicate Ceramic

The purpose of this prospective study was to evaluate the clinical long-term outcomes (over ≥ 15 years) of crown-retained fixed dental prostheses (FDPs) made from a lithium disilicate ceramic (IPS e.max Press, Ivoclar Vivadent). A total of 36 three-unit FDPs replacing anterior (16%) and posterior (84%) teeth were placed in 28 patients. Abutment teeth were prepared following a standardized protocol. The size of the proximal connector of the FDPs was 12 mm² (anterior) or 16 mm² (posterior). FDPs were cemented either conventionally with glass-ionomer cement ($n = 19$) or adhesively with composite resin ($n = 17$). The following parameters were evaluated at baseline, 6 months after cementation, and then annually at the abutment and contralateral teeth: probing pocket depth, plaque index, bleeding on probing, and tooth vitality. Three FDPs were defined as dropouts. The mean observation period of the remaining 33 FDPs was 167 months (range: 79 to 225 months). The survival rate (survival being defined as FDPs remaining in place with or without complications) according to Kaplan-Meier was 48.6% after 15 years. The success rate (success being defined as free of complications and remaining unchanged) was 30.9% after 15 years. Fatigue and crack propagation caused by clinical aging in monolithic lithium disilicate ceramics seem to take considerable time, as shown by the presented survival and success rates after 15 years. Further long-term studies are necessary to evaluate the reliability of FDPs made from other all-ceramic materials over a period of ≥ 15 years.

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