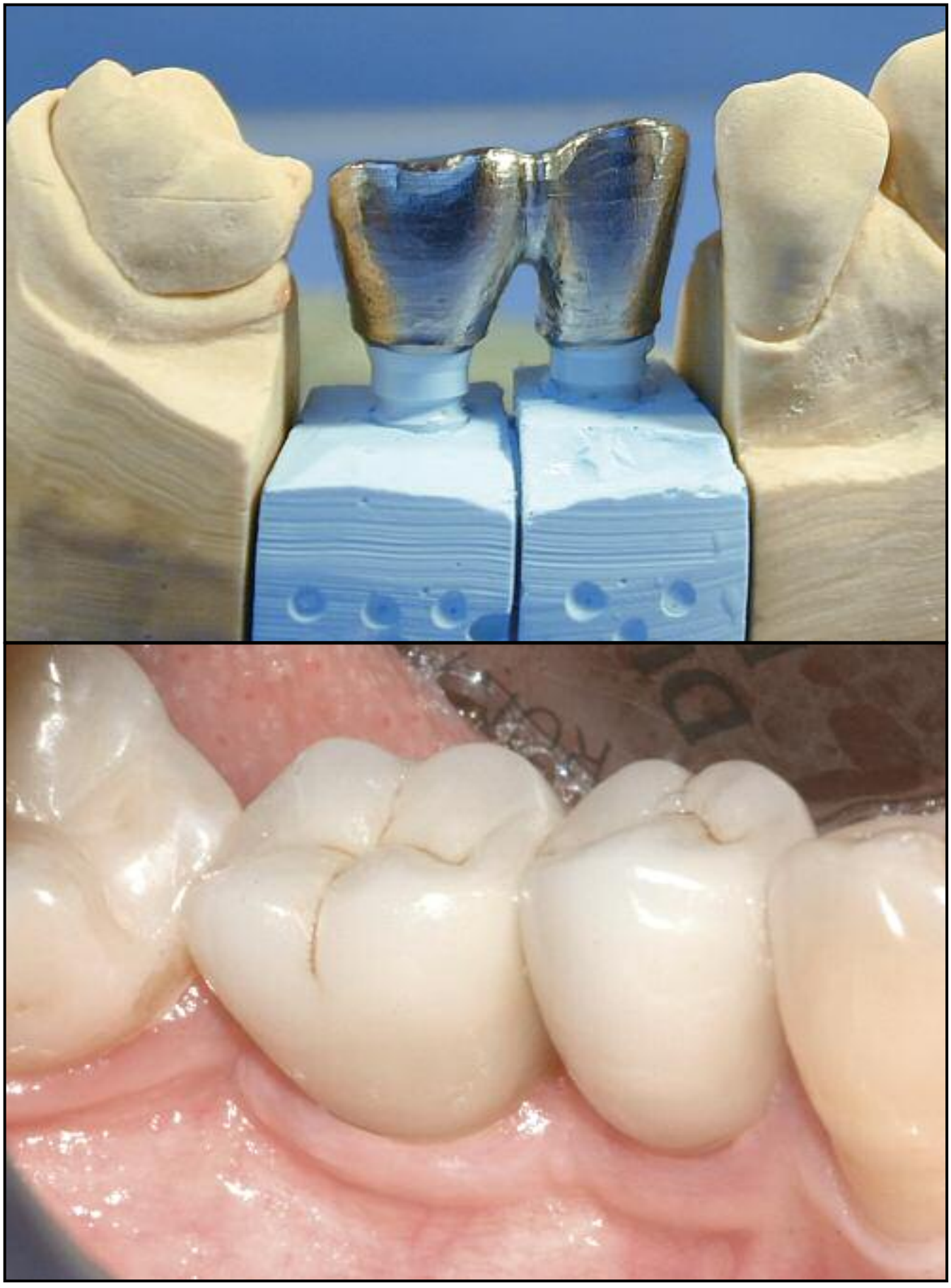

The Abutment Duplication Technique: A Novel Protocol for Cementable Implant-Supported Restorations

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The purpose of this study was to present a new laboratory technique for cementable implant-supported restorations and to evaluate its efficacy in reducing chair time for both patients and clinicians, while maintaining the precision of an indirect procedure for crown fabrication. The technique consisted of the duplication of the implant portion of a working cast prepared using double-pour or plastic base die systems for single or multiple crowns. For this purpose, a flask previously intended for the production of ceramic inlays and onlays was used. Duplication was obtained using a high-precision addition silicon material and a low-shrinkage polyurethane resin. The duplicated implant abutment was used to finalize the fixed partial denture restorations after the originals were delivered to the patients. Fifty abutments were tested consecutively. The castings (19 single crowns, 31 fixed partial dentures) produced on the original abutments were seated on the duplicate abutments and evaluated by two prosthodontists and two dental technicians using a visual inspection method (laboratory microscope at 16× magnification). Forty-eight restorations were "good" (completely seated, no marginal opening) and 2 were "acceptable" (incomplete seating but amendable), with a 98% success rate. The technique presented demonstrates efficacy and predictability in reducing the number of clinical sessions for delivering precisely fitting cementable implant-supported restorations. (Int J Periodontics Restorative Dent 2010;30:415–424.)

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Fixed restorations on endosseous implants are usually either screw- or cement-retained. For screw-retained crowns, the crowns are connected to the implants with screws (either directly or through a provisional abutment). For cement-retained crowns, abutments that have been contoured and shaped as prepared teeth for conventional fixed prosthodontics are connected to implants with abutment screws, and the crowns are cemented to the abutments. In the last few years, the cement-retained protocol has gained popularity,[1,2] particularly in partially edentulous patients.

The main reasons for this emerging popularity include:

- Easier correction of angulation problems.[3] The ideal anatomical axis for implant insertion, centered buccolingually in the alveolar process, may not correspond to the ideal prosthetic axis, with the screw access opening in the central fossa of clinical crowns. This tends to present more frequently in the maxilla because of the resorption pattern seen there. Sometimes, the implant axis may

be tilted intentionally in the mesiodistal direction.[4] In these situations, cemented restorations may be the treatment of choice.
- Screw-retained implant crowns may result in poor esthetics because of the location of the screw access openings. This occurs more frequently in the mandible because the screw access openings tend to be more visible. This situation was once thought to be insignificant, but now has greater importance because of the increased esthetic expectations of many patients. Moreover, screw access openings weaken the integrity of the ceramic layers of crown restorations when loaded during function.[5,6]
- When multiple implants are splinted with fixed restorations, the use of cement-retained crowns allows for easier, more accurate adaptation. This has been implicated by decreasing stress between the fixed prosthesis and the implant abutments through the use of controlled thicknesses of cement between the abutments and the crowns.[7–9]
- Cement-retained protocols are more familiar to restorative dentists and laboratory technicians because the procedures are similar to those used in traditional prosthodontics.[2]

Cement-retained protocols may be implemented in several different ways.

Direct method

A prefabricated abutment is connected to an implant and prepared intraorally with rotary instruments. Anatomically preshaped abutments, straight or angled, are available to clinicians in most implant systems. Unfortunately, intraoral preparation of implant abutments is more difficult to accomplish when compared to crown preparations of natural teeth. Metal or zirconia abutments, because of their different physical properties, tend to spread small pieces of debris from the abutments into the surrounding soft tissues. The definitive restorations are made from intraoral impressions fabricated using conventional fixed prosthodontic impression materials. Intraoral impression procedures for implant abutments tend to be more difficult than impressions of natural teeth, especially those with subgingival margins. Retraction cord placement into the peri-implant sulcus may damage the epithelial attachment, which forms onto the sulcular surface of abutments. However, if a retraction cord is not used, there is the possibility for fragments of the impression material to remain undetected in the sulcus and produce inaccurate impressions. Retained subgingival impression material may induce pocket formation and fistulae.

Working casts are then developed in die stone or epoxy resin. The dies are sectioned and trimmed in a conventional fashion for fabrication of the crown restorations. The quality of a marginal adaptation when the crown restoration is made on an abutment duplicated in stone or epoxy resin from a traditional impression procedure is significantly inferior when compared to that prepared via indirect procedures.[10] Therefore, there is increased risk of open margins, bacterial proliferation, and gingival inflammation.

Indirect method

Implant abutments are fabricated in a laboratory on a cast obtained from an implant-level impression. The master cast contains an implant analog that replicates the orientation of the implant intraorally, as well as the peri-implant soft tissue contours. Prefabricated titanium or zirconia abutments are placed onto the analog in the master cast and prepared, much as one would prepare a natural tooth for a crown restoration. As an alternative, abutments can be produced via waxing and casting customized abutments or can be custom-milled from a computer-generated dataset. The indirect method allows for an ideal and precise abutment design.

Provisional crowns may also be fabricated in a dental laboratory and sent with the abutments to clinicians if a provisional loading phase is planned. One protocol also requires that the superstructure is waxed and cast on the abutments, tried in the mouth, and then sent back to the laboratory for ceramic baking. Provisional loading is therefore eliminated and sometimes this may negatively affect the clinical outcome. Moreover, the abutments are connected and disconnected to the implants several times, with possible detrimental effects on soft tissue stability through repeated disruptions

of the epithelial attachments around the implants.[11] Another possible consequence of this protocol comes from the fact that if an abutment is repositioned on an implant at different times, a phenomenon defined as "sliding misfit" can occur. This can lead to a difference in the rotational position of the abutment on the implants, resulting in possible problems with the seating of the superstructure.[12]

As an alternative, superstructures may be cast on the original abutments, which are then placed into function with provisional crowns. At a later time, the superstructures are repositioned on the abutments and a transfer impression is made. This impression is used to fabricate the secondary cast for the definitive prostheses. This has been the technique preferred by the authors because it combines precise marginal adaptation of the crowns onto the abutments along with the advantages of temporary loading. The major disadvantage of this technique is that it requires a clinical appointment for the transfer impression to develop the secondary cast. Moreover, during temporary loading, one or more implants may fail and the superstructure, previously cast, must be discarded. This represents a financial loss to the practitioner and potentially, to the patient.

Direct/indirect method

In some cases, provisional abutments (usually composed of durable, strong plastic materials) are connected to the implants, prepared intraorally, and loaded with provisional restorations. For the definitive restorations, an indirect protocol is followed, starting with an implant-level impression. Clinicians and dental laboratory technicians may encounter some or all of the problems described previously. This technique is often part of an immediate loading procedure. However, it may not be used on a routine basis because of the increased costs associated with using two different abutments.

Double-milled abutment method

Recently, a computer-aided design/computer-assisted manufacturing protocol was proposed[2] in which two abutments are milled from the same dataset. One abutment is placed intraorally for the provisional phase and the second abutment is positioned in the original master cast for the construction of the definitive restoration. With this technique, the authors have found that the differences in the two abutments are minimal. However, the major problem associated with this method is the significantly increased costs.

Because of the multiple variables involved in the aforementioned procedures, the purpose of this paper is to present and evaluate a new protocol for cement-retained implant prostheses. This protocol was developed to produce repeatable technical results and reduce the total chair time and the costs associated with the protocols just described.

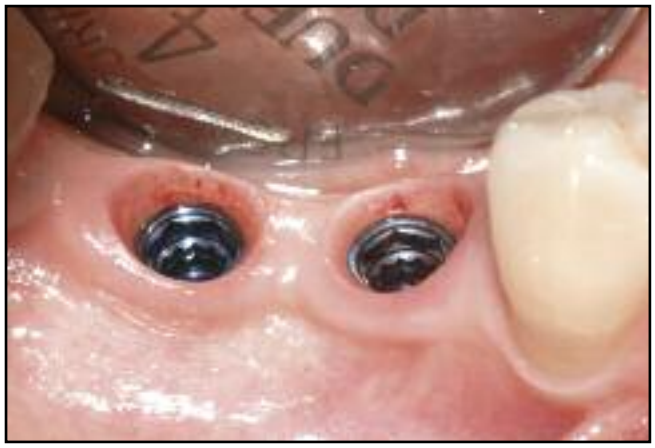


Fig 1 *Two posterior mandibular implants were used to replace the right second premolar and first molar.*

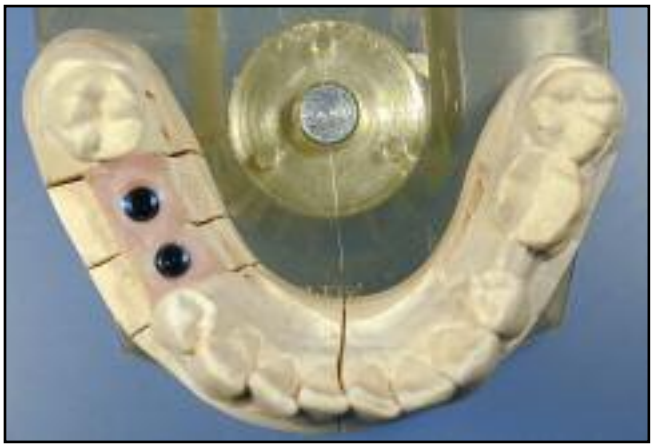


Fig 2 *The master cast with the implant analogs in place. The dies were sectioned within the cast.*

Method and materials

The proposed abutment duplication technique relies on duplication of part of a sectioned working cast, namely the abutments assembled to the implant analogs. The duplicated section can be used on the original cast to complete the definitive restorations after the original abutments have been placed in the patient's mouth. This may be accomplished using cast systems that can be sectioned to compensate for the linear expansion of dental stone (double-pour or plastic base die systems). The casts produced with these systems have been demonstrated to be more accurate than solid casts.[13–15]

Two systems were used in developing this technique: the Zeiser system (Zeiser Dentalgeräte) and the Giroform system (AmannGirrbach).

Both systems include duplicating flasks (a single, adjustable flask for the Giroform system and four different sizes for the Zeiser system). These devices were originally developed to duplicate stone dies in refractory material for teeth prepared to receive ceramic inlays or onlays. Similarly, they can be used to duplicate the implant section of working casts.

After the cast was prepared consistent with the system used, it was sectioned and separated into two parts: the implant-supported portion and the remaining portion of the dental arch (Figs 1 and 2). The cast was mounted on an articulator and the implant abutments were developed according to optimal mechanical and anatomical requirements (ie, height, taper, emergence profile, and type of finishing line) (Fig 3). The superstructure for a cement-retained prosthesis was waxed and cast onto the definitive finished and polished abutments following the indirect method previously described (Fig 4). The screw access openings in the abutments were obliterated with cotton pellets and a soft composite material prior to waxing of the superstructures.

Fig 3 *The premachined abutments were prepared and finished on the implant lab analogs in the original master cast.*

Fig 4 *The superstructure was waxed and cast on the prepared abutments seen in Fig 3.*

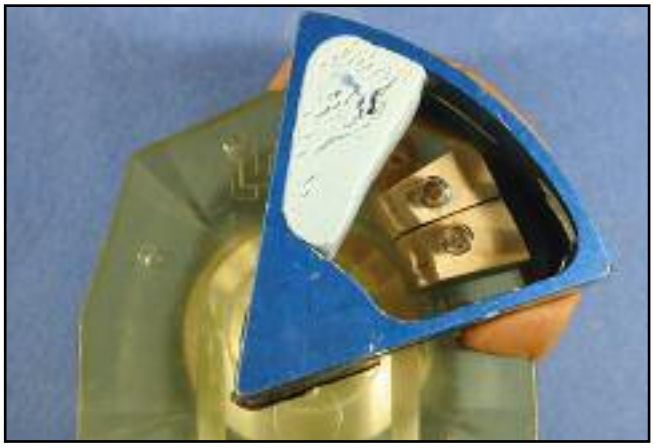


Fig 5 *The duplicating flask was mounted on the cast base, including the section to be duplicated.*

Fig 6 *The addition reaction silicon was poured into the flask.*

The nonimplant portion of the working cast was removed and the duplicating flask was connected to the cast plate around the implant-supported section (Fig 5). An accurate addition-curing silicon impression material (Adisil Blue, Siladent Dr Böhme and Schöps) was vacuum-mixed for 40 seconds at a precise base/catalyst ratio of 9:1 by weight, and poured into the flask. Care was taken to avoid forming any bubbles and to completely cover the abutment (Fig 6). The material was left to set for 30 minutes and the flask was disassembled. A polyurethane resin (PX Extrarock, PX Dental) was chosen as the duplicating material because of its excellent physical properties; in particular, its linear retraction (0.29% for a 50-mm-thick sample). The material was mixed according to the manufacturer's instructions (component A and component B were mixed at a precise 9:1 ratio by weight) and poured into the perfectly dried impression mold in

Fig 7 *Polyurethane resin was poured into the silicone mold.*

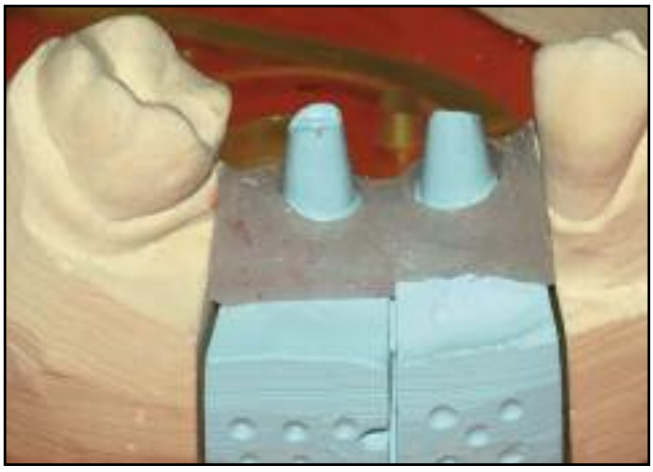


Fig 8 *The duplicated polyurethane abutments were placed on the original master cast.*

Table 1 Types of restorations

	Maxilla	Mandible	Total
Single-unit	12	7	19
Two-unit (splinted)	7	6	13
Three-unit (splinted)	7	4	11
Three-unit FPDs (one pontic)	3	4	7
Total	29	21	50

small increments until the mold was filled completely (Fig 7). Care was taken to avoid trapping any air bubbles. The cast plate was reconnected to the duplicating flask after new cast pins were placed into positions corresponding to the section to be duplicated. The resin hardened in approximately 1 hour. At this point, the cast was reassembled and the result was a "hybrid" cast, in which the implant-supported section was a precise replica of the original abutment/analog set (Fig 8). This provided sufficient accuracy to the cast; the superstructure could be waxed and cast as it would on the original abutments.

To evaluate the efficacy of this procedure, a clinical method was chosen according to similar studies.[16] For this report, 50 consecutive clinical restorations (single units or short-span fixed partial dentures [FPDs]) have been included (Table 1). The total number of implants restored was 112; 18 implants had an external-hexagon prosthetic connection (Osseotite, Biomet 3i) and 94 had an internal connection (Certain, Biomet 3i).

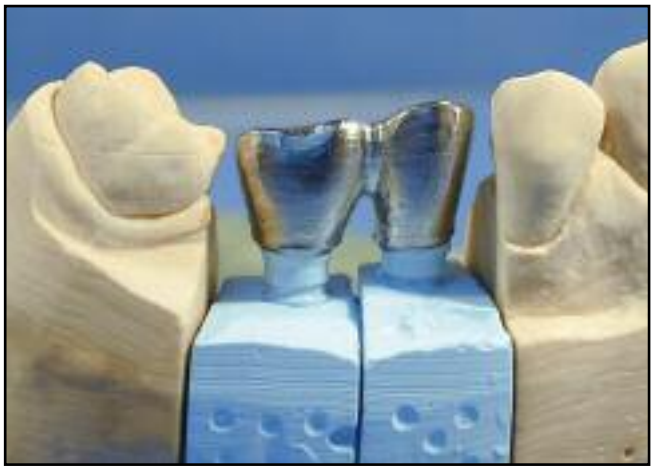


Fig 9 *The castings placed on the duplicated abutments. This cast was used for the definitive metal-ceramic restorations.*

Fig 10 *Provisional crowns were transferred to the duplicate abutments on the master cast.*

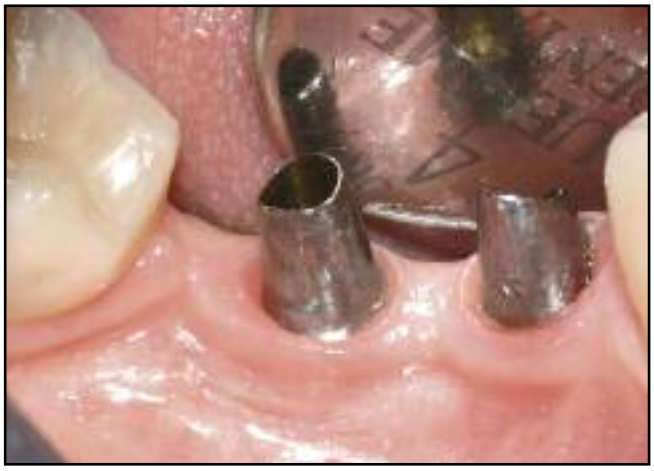


Fig 11 *Titanium abutments were placed intraorally on the implants. The buccal margins were designed to be slightly subgingival for optimal esthetics.*

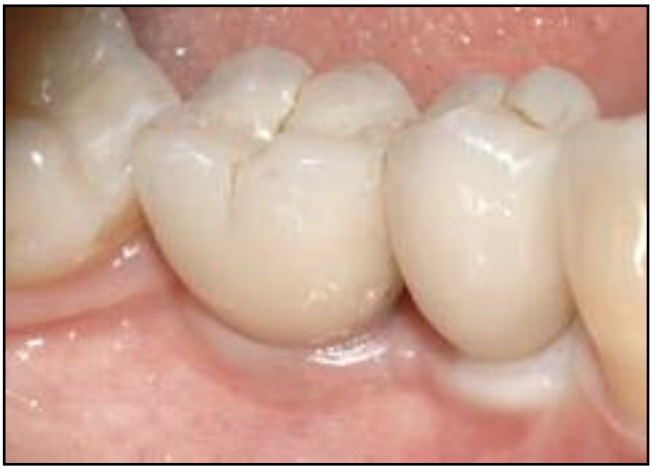
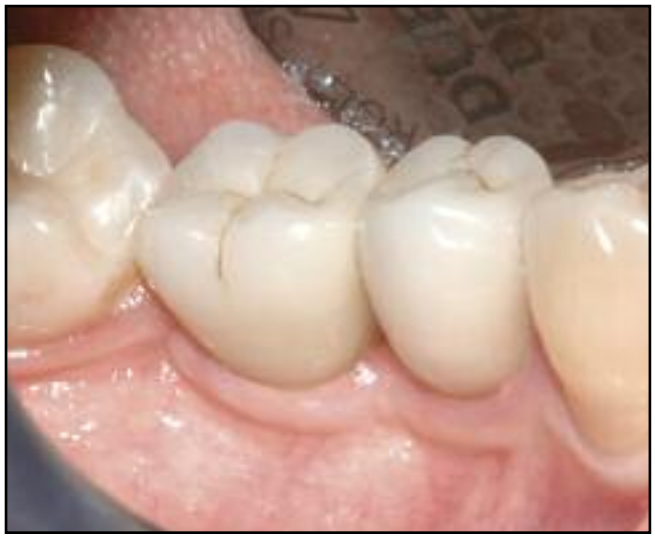
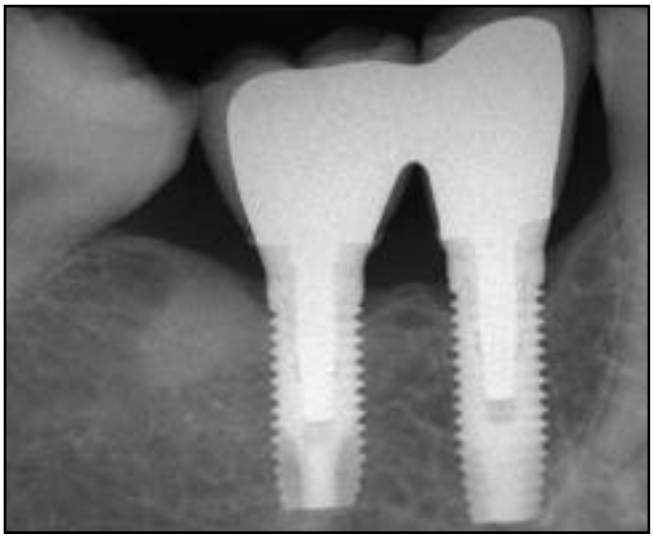


Fig 12 *The provisional crowns were cemented onto the definitive abutments intraorally. Note the bleaching of the marginal gingiva around the second premolar because of the initial shaping effect of the crowns' emergence profiles.*

Every patient was assigned consecutively to one of the two duplication systems used in the study. In every patient, the abutments were produced and duplicated, then the superstructures were waxed on the original abutments and cast in noble alloy for porcelain-fused-to-metal restorations. Each finished casting was seated onto the original abutments and then transferred onto the duplicated abutments, which had been previously repositioned on the cast (Figs 9). The castings were examined with a laboratory microscope at 16× magnification by two qualified dental technicians and two prosthodontists. For each sample, ease of seating and marginal adaptation on the duplicated abutments were evaluated and scored as "poor" (the duplicated cast was not usable to finish the restoration), "acceptable" (some difficulties in seating but amendable), or "good" (no problem in seating and good marginal adaptation). In all patients, the provisional crowns were then cemented to the abutments (Figs 10 to 12), followed by the definitive crowns made on the duplicate casts (Figs 13a and 13b).





Figs 13a and 13b (left) *The definitive restorations were cemented intraorally.* (right) *The verification radiograph indicates precise marginal adaptation between the crowns, abutments, and implants.*

Results

No sample was scored as "poor"; only two were scored as "acceptable" and the rest were scored as "good." In all patients, the duplicated sections allowed for easy and predictable completion of the definitive restorations. The two restorations that were scored "acceptable" were both FPDs (one three-unit and one two-unit), and both had been duplicated using the Zeiser system. When the casts were transferred to the duplicated dies, they did not seat completely and had to be cut and soldered. Both cases were completed on a secondary master cast developed from a transfer impression.

Discussion

Cement-retained implant-supported restorations are widely used and may be fabricated with either direct or indirect protocols. The ideal clinical and laboratory protocol should be precise, repeatable, cost effective, and biologically and clinically acceptable. It should also minimize the number of clinical sessions and use simple intraoral procedures that respect the delicate periimplant attachment apparatus. A technique in which the definitive abutment is positioned and never disconnected is considered to be ideal, but problems are associated with fabrication of the definitive restoration on a replica of the original abutment in a laboratory. This may be accomplished by making an intraoral impression of the abutment, but as demonstrated by Ganz, this may not lead to consistently accurate results in terms of marginal adaptation.[10]

The results obtained in the present study (2 "acceptable" restorations, 48 "good" restorations; cumulative success rate, 98%) were satisfactory. Both restorations that required modification were external-hexagon implants restored with UCLA-type abutments. In these restorations, the maximum preload was obtained by delivering a torque force of 35 Ncm to the abutment screws. In these situations, one or more abutments can undergo rotational displacement, which, even if minimal, prevents the full seating of the multiple-unit splinted superstructure.

In the other cases, the implants used had internal implant-abutment connections where the maximum preload was obtained with only a 20-Ncm torquing force to the abutment screw. This effectively eliminated the risk of the previously mentioned "sliding misfit." Moreover, the majority of cases (83 implants) were treated with preparable premachined titanium abutments (GingiHue Posts, Biomet 3i). Generally, these premachined titanium abutments have a more precise fit with implants compared to castable UCLA-type abutments, which can undergo unpredictable dimensional modifications resulting from the many variables of the casting process.

The high predictability demonstrated by the presented technique can be ascribed to the accuracy of the impression technique and the properties of the resin material. The silicone impression material used in this study has reproduction accuracy, according to the manufacturer, within 0.001 mm. Moreover, the duplication systems used in this study have been in use for several years. The flasks have been used for different indications than those described here, but have been widely accepted in prosthodontic practice.

The use of epoxy resin dies in prosthodontics is well documented in the literature, but very little has been published on polyurethane resins. Darrien and Sturtz,[17] using scanning electron microscopy and two-dimensional profilometry, demonstrated that both epoxy and polyurethane resins can reproduce details of 1 to 2 μm, while artificial stone could not reproduce details smaller than 20 μm. In another study,[18] the authors stated that incorporating silica fillers in the resin reduced dimensional variations and improved accuracy. Kenyon et al[19] compared seven die materials and found that polyurethane resin had a combination of linear expansion and shrinkage. According to the manufacturer, the material used in the present study tends to shrink minimally. Therefore, it is not surprising that the castings seated easily onto the duplicated abutments, with no visible marginal openings. If the dies were undersized significantly, this would be easily detected under the 16× magnification microscope used in this study. Therefore the casts with the duplicated sections were safely used for the definitive crown restorations, while the original abutments were already in clinical use. There was no need for further impressions to develop a secondary cast. Based on the 4 years of experience that the authors have with this technique for single crowns and small FPDs, it was often possible to avoid clinical try-in appointments with porcelain in bisque bake. The authors found that this appointment was eliminated and treatment could move directly to the insertion of the definitive restorations, with only small adjustments of the interproximal contact areas needed.

The additional costs of the procedures were limited to purchasing of the duplicating flasks. These flasks were developed for indefinite laboratory use. Another limitation with this protocol may be that the technique can be applied only to sectioned cast systems, which include duplicating flasks. However, the two systems tested by the authors are widely used in many dental laboratories, especially in Europe, and therefore the proposed technique may be of some interest to a number of clinicians.

The need for a duplicate cast for an easier and more precise indirect technique has produced interesting results, such as computer-milled abutment technology.[2] This confirms preexisting interest in this aspect of restorative implant treatment. The technique proposed in this paper does not require sophisticated technologies and can be applied to any type of abutment production technique at a significantly lower cost. Moreover, the high accuracy of the duplication technique may allow the use of duplicated abutments as primary dies for waxing and casting superstructures with great predictability. A study is currently ongoing to verify this hypothesis.

Conclusions

With the simple, repeatable, and cost effective laboratory procedure described in this paper, the prosthetic protocol for cement-retained implant restorations has been modified to obtain several advantages for clinicians, dental laboratory technicians, and patients.

- The definitive abutments are produced through an indirect, precise, laboratory procedure.
- It is possible to connect abutments to implants with the optimal preload at the time of provisionalization. In this "one abutment–one time" concept, the

definitive abutments do not have to be removed from the implants at any future date in the restorative process. This allows a stable epithelial attachment to form directly onto the abutments. This eliminates disturbance of the delicate epithelial attachment with unnecessary multiple disconnections and reconnections and with invasive procedures such as packing retraction cord and intrasulcular impressions to develop master casts. This also reduces the chair time associated with restorative procedures.

- This protocol allows patients to have rapid restoration of their esthetics and function at the clinical session following the initial impression, with provisional crowns cemented onto definitive abutments. In case of provisional crown fracture, the crowns can be repaired easily or remade on the duplicated casts.
- Technicians finalize prostheses on original casts with duplicated reproductions of the definitive abutments. This is done without additional impressions. The laboratory portion of the treatment can be planned at times most convenient for the patients, clinicians, and laboratory technicians. After completing the treatment, the casts and provisional crowns are stored at the office and can be used again if the need arises (ie, ceramic fracture or repair).

Acknowledgments

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