



Root Analog Zirconia Implants: True Anatomical Design for Molar Replacement—A Case Report



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Replacement of lost teeth using oral implants is an accepted treatment modality with well-documented high long-term success rates. Conventional screw- or threaded cylinder-type implants have been used almost exclusively. Their incongruence with the extraction socket necessitates the use of a barrier membrane or bone augmentation to prevent down-growth of connective tissue or epithelium between the implant and socket. Although some minor changes in implant design have been made, the neck and abutment connection areas have not changed much in the past 30 years. Custom-made root analog implants have been employed clinically in rare instances; however, they yielded failure rates of up to 96% at 1 year of follow-up. So far, ovoid implants are the closest in design regarding resemblance to the natural tooth anatomy. Root analog zirconia implants with macroretentions were developed and produced for immediate single-stage replacement of missing or hopeless teeth. This article discusses the treatment and 3-year follow-up of a patient with such an implant for replacement of a maxillary molar. (Int J Periodontics Restorative Dent 2011;31:663–668.)

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Replacement of lost teeth using oral implants is an accepted treatment modality with well-documented long-term success rates of between 90% and 100% at 10 years of follow-up.¹ The timespan between tooth extraction and implant insertion has become shorter over time. Originally, a healing period of 6 to 9 months was recommended before implant insertion (late implant placement). Later on, earlier placement of implants after 2 to 3 months was proposed (delayed implant placement), and, more recently, immediate implantation within a few days of tooth extraction has been performed clinically, although only in highly selected cases.² Results with shorter intervals between extraction and implantation are comparable to those of late implant placement. The major advantages of immediate implant placement are the decrease in the treatment time for the patient and the reduction in the number of surgical interventions, resulting in an improved quality of life and overall cost reduction. Furthermore, alveolar bone resorption and soft tissue

regression are significantly reduced because of early—albeit limited—functional load.

Commercially pure titanium has been the material of choice for dental implants and abutments for the past 30 years, primarily because of its well-documented biocompatibility and mechanical properties. The success rate with this material is high; however, there is the disadvantage of the black metallic components showing through the mucosa or becoming visible in cases of soft tissue recession. Only recently, tooth-colored ceramic abutments and implants were developed to achieve optimal mucogingival esthetics. Zirconia possesses good mechanical properties, such as high flexural strength and hardness, and is capable of withstanding simulated long-term loading.³ Furthermore, it is highly biocompatible, with a capacity for osseous integration comparable to titanium implants, and less prone to plaque accumulation than metal substrates.

Another trait that has hardly changed over the past 30 years is the form of dental implants: rotationally symmetric screw- or threaded cylinder-type implants. Minor modifications of the shape have led to the use of tapered and ovoid implants, which are still far from resembling the natural tooth anatomy. The problem associated with immediate implant placement using these conventional implants is the incongruence with the extraction socket, necessitating the use of a barrier membrane or bone augmentation to prevent down-

growth of the connective tissue or epithelium in between the implant and socket.⁴

Hodosh and colleagues⁵ were the first to tackle the problem of incongruency by employing a novel approach of custom-made root analog implants placed into the extraction socket. By adapting the root to the extraction socket instead of the vice versa approach of adapting the bone to a preformed standardized implant, they reduced the bone and soft tissue trauma. Experimental studies in monkeys yielded extremely favorable results with clear evidence of osseointegration and clinical stability in 88% and 100% of implants at the end of the experimental period, respectively.^{6,7} The ensuing clinical trial resulted in 100% primary stability at insertion and the 1-month follow-up. Because of the high failure rate of 48% over the short time period of 9 months, this particular implant system was not recommended for clinical use.⁸

The authors selected a significantly modified approach by (1) using a new biomaterial, zirconia, for improved esthetic results by preventing dark discolorations of the gingiva and display of titanium roots in cases of gingival recession, as well as for its high compressive strength and bending forces and high electrical resistance; (2) choosing an anatomically oriented design by copying the extracted tooth; (3) employing novel surface technologies by not only adding microretentions to the entire root surface but also macroretentions limited to the

interdental space to get beyond primary stability and allow for osseointegration beyond the period of 1 month and bone remodeling; (4) reducing the diameter of the implant next to the thin cortical bone to avoid fracture and pressure-induced bone loss; and (5) employing a single-stage implantation strategy resulting in immediate—albeit reduced—functional loading via the crown stump for prevention of bone resorption as a result of involution.

Case presentation

A 41-year-old woman presented with a fractured maxillary left second molar (Fig 1). The patient's oral hygiene was poor. The fractured tooth and the neighboring teeth were carious. A panoramic radiograph showed no signs of periodontitis. After informed consent was obtained, the tooth was carefully extracted under local anesthesia (Ultracain DS forte, Aventis), avoiding any damage to the hard and soft tissue (Fig 2). The extraction socket was cleaned by means of curettage followed by saline irrigation, and an iodoform-soaked cotton gauze was placed in the wound. The fractured tooth was glued together (Fig 3), the root was laser scanned, and macroretentions were designed according to the study protocol and strictly limited to the interdental space, sparing the buccal and lingual face to prevent fractures of the thin cortical bone layer at the point of insertion (Fig 4). On top of the root, a stump



Fig 1 (left) Initial examination: Occlusal view of the fractured maxillary left second molar.

Fig 2 (right) Extracted tooth.



Fig 3 (left) Extracted tooth glued back together.

Fig 4 (right) Extracted tooth with macro-retentions limited to the interdental space molded on the surface next to the zirconia implant.



was designed for later connection to the crown. The root was milled from a zirconium dioxide block (yttria-stabilized tetragonal zirconia polycrystal), and the surface was roughened by sandblasting and sintered for 8 hours to achieve the desired mechanical properties. Thereafter, the implant was cleaned in an ultrasonic bath containing 96% ethanol for 10 minutes, packaged, and sterilized in a steam sterilizer. On day 6, the iodoform cotton gauze was removed and the alveolar socket was again curetted and flushed with sterile physiologic saline solution. The custom-made

individualized implant was placed into the socket under finger pressure and subsequent gentle tapping with a hammer and mallet (Fig 5). Primary stability was achieved, as checked by palpation and percussion. The implant completely filled the extraction socket, ensuring perfect osseointegration. The patient received postoperative analgesics (Parkemed 500 mg, Pfizer) on demand and antibiotic medication (Augmentin 625 mg, Galaxo-SmithKline) for 4 days. She was instructed to chew predominantly on the contralateral side and avoid hard foods.



Fig 5 (left) *Implant in situ immediately after insertion.*

Fig 6 (right) *Perfectly healed gingiva around the zirconia implant at 2 weeks postimplantation.*



Fig 7 (left) *Buccal view of the definitive restoration.*

Fig 8 (right) *Lateral view of the definitive restoration at the 3-year follow-up.*



Fig 9 (left) *Radiograph taken at the 3-year follow-up with the zirconia implant and crown in situ.*

Ten days after implant placement, the marginal area showed no signs of inflammation, and no postoperative pain or swelling was reported. There was no bleeding on probing or wound infection. The color of the soft tissue was identical to that around the neighboring teeth, giving the site a natural appearance (Fig 6). An acrylic resin crown was cemented onto the implant, and the definitive prosthetic restoration was

delivered at 7 months after tooth extraction (Fig 7). At 3 years, the patient presented with a stable implant; unchanged peri-implant marginal bone levels; no signs of apical implantitis, as monitored by radiographs and soft tissue parameters; and no bleeding on probing (Figs 8 and 9). Hence, in addition to an excellent esthetic result, there were no signs of periodontitis or bone resorption.

Discussion

To the authors' knowledge, the present report describes the first successful immediate replacement of a two-rooted tooth with an individualized two-rooted zirconia implant. This novel concept was introduced by the same group of authors, and the details of the methodology were published in a technical note in 2008.⁹ The clinical investigation of these truly anatomical zirconia implants for immediate replacement of single-rooted teeth yielded excellent results, which were sustained for the entire follow-up of 2 years.¹⁰

The concept of replacing teeth with custom-made root analog implants is not new. A tooth replica implant was reported as early as 1969; however, the autopolymerized and heat-processed polymethacrylate used to fabricate the tooth analog was encapsulated by soft tissue rather than osseointegrated.⁵ Lundgren and colleagues⁶ reintroduced the idea of root analog implants in 1992. Instead of using polymers, titanium was used in an experimental model of immediate implant placement leading to bony integration in 88% of the surface area. A good fit between implant and the host bed has been described as an important factor for implant success.^{11,12} For that reason, Kohal et al⁷ further refined the approach of root analog titanium implants by widening the coronal aspect of the implant to compensate for the lost periodontium and to obtain a good congruence between implant and

extraction socket. In several instances, implant insertion led to fracture of the thin buccal wall of the alveolar bone. An ensuing clinical study performed by the same group described excellent primary stability of root analog titanium implants sustained up to 1 month, with a highly disappointing failure rate of 48% at 9 months. A perfect fit of the implant without any retention leads to excellent primary stability; however, at the same time, it might be responsible for the intermediate-term failure because of the subsequent uniform pressure-induced resorption concerning the entire alveolar surface simultaneously.

A cross-section of the jaws shows that there is only sufficient room for enlargements and retentions in the interdental space, whereas the thin buccal and lingual layers do not allow for any enlargement of implants in this area. For these reasons, the authors chose a significantly different approach, manufacturing root analog implants with macroretentions in the interdental space and an implant diameter reduction of 0.1 to 0.5 mm next to the buccal cortical bone. The surface was roughened by sandblasting, resulting in enhanced bone integration. Zirconia implants, which have been shown to osseointegrate to the same extent as titanium implants, were used to achieve better esthetic results and because of their superior mechanical properties.¹³ Furthermore, a single-stage implant approach with a crown stump was chosen since it leads to an early but reduced functional load, still allowing

for osseointegration because of the maximized implant-bone contact surface while preventing the unesthetic early bone resorption observed with submerged implants. While successful immediate loading protocols with commercially available implant types require a careful and strict patient selection, the current novel approach leads to a high degree of primary stability and shorter healing periods, allowing for immediate loading.

The case described, which is part of a larger ongoing clinical trial, demonstrates that immediate placement of significantly modified, root analog, nonsubmerged zirconium dioxide implants yields excellent results superior to previously described custom-made root analog titanium implants with a uniform shape.

Conclusions

To the authors' knowledge, this case represents the first report on the successful clinical use of an immediate, single-stage, root analog zirconia implant for replacement of a two-rooted tooth. Significant modifications such as macroretentions seem to indicate that primary stability and excellent osseointegration of such implants can be achieved while preventing unesthetic bone resorption. The macroretentions have to be limited to the interdental space to avoid fracture of the thin cortical layers. The described technology is a combination of a truly anatomical implant design and the use of a new biomaterial

and surface technology, including both micro- and macroretentions. This novel approach is minimally invasive, respects the underlying anatomy, is time- and cost-effective with improved esthetic results, and yields increased patient acceptance. This promising technology warrants further clinical research in well-controlled trials.

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