Digitally customised asymmetrical zirconium dental implant

Replacement of a mandibular molar—Surgical and prosthetic aspects

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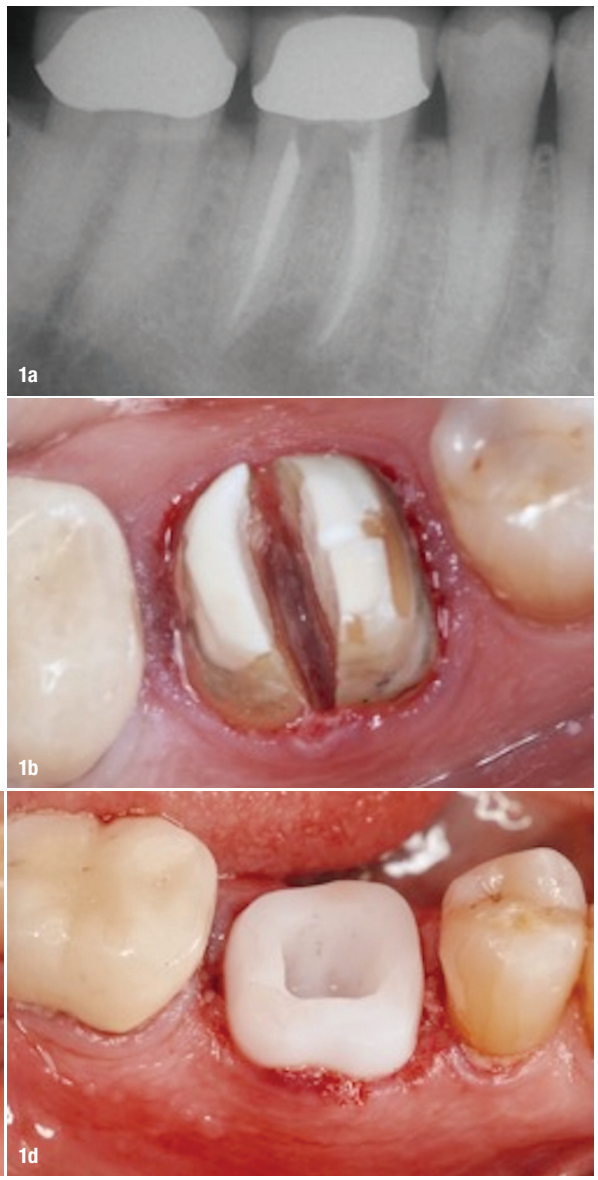
Abstract

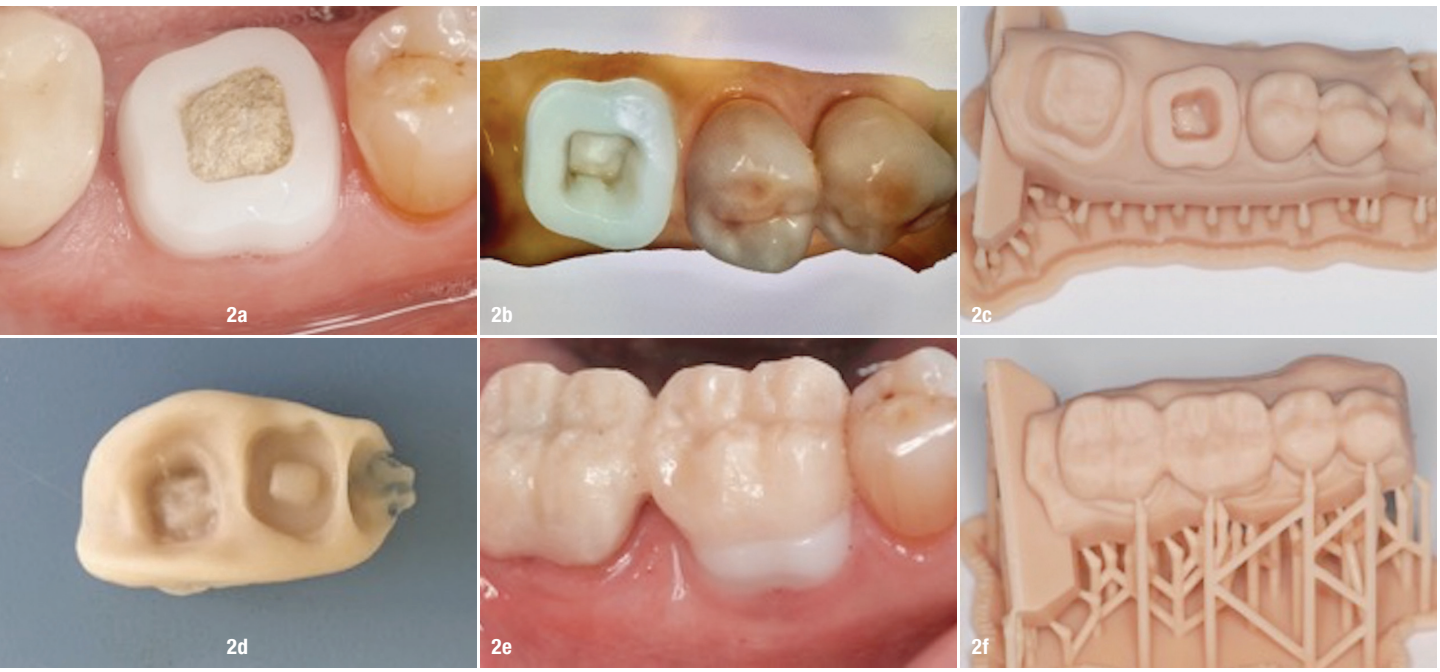
To reduce the overall treatment time required for replacement of a tooth with an implant-supported crown, clinicians will place the fixture immediately after an extraction. Under appropriate circumstances, especially in the anterior aspects of the jaws, this approach yields highly predictable functional and aesthetic results. In the posterior areas of the jaws, the anatomy of roots often compromises the available volume of bone to the extent that it is not possible to achieve primary stability of an immediately placed implant. To circumvent this issue, a customised two-piece implant system was designed in which the shape of the intraosseous component corresponds to the actual anatomy of the extracted tooth. The case report describes the implant and illustrates how it can be immediately placed following extraction of a mandibular molar that had a hopeless prognosis.

Introduction

Although initially intended to support mandibular fixed full-arch restorations by following very rigid surgical and



Figs. 1a–d: Extraction of tooth #30 and placement of customised zirconium implant. Radiograph demonstrating periapical pathology on #30 **(a)**. Hemisection of #30 to facilitate minimally traumatic extraction **(b)**. Extraction socket with intact buccal alveolar bone **(c)**. Zirconium implant in place demonstrating immediate support of adjacent peri-implant soft tissues **(d)**.



Figs. 2a–f: Provisionalisation of the zirconium implant. Healthy peri-implant soft tissues six months after implant placement **(a)**. Scanned digital impression **(b)**. 3D-printed model derived from digital impression **(c)**. Block carving of provisional crown **(d)**. Provisional restoration cemented in place **(e)**. 3D-printed model derived from digital scan of the provisional restoration **(f)**.

prosthetic protocols,[1] implants are now placed via either immediate[2–4] or delayed approaches and subsequently used to support dentures, crowns and/or bridges (fixed partial dentures) to address partial edentulism in all parts of the mouth. Often, extraction of a molar with the intention of replacing it with an implant-supported crown is achieved via a delayed protocol due involving placement of a bone graft to preserve the morphology of the alveolar ridge.[5] In other situations, the walls of the socket are not intact, requiring an actual guided bone augmentation procedure to re-establish sufficient volume for implant placement. Both approaches typically yield a flat crestal bone profile that does not restore the normal osseous architecture present around healthy teeth. This, in part, contributes to less-than-ideal aesthetic results and crestal bone resorption.

The morphology of the portion of natural teeth that is positioned between the bone crest and gingival margin (transition zone) is highly variable, ranging from the rather simple ovoid shape of mandibular incisors to the highly complex rhomboidal shape of maxillary molars. With the implants in use today, dentists and laboratory technicians must reproduce this aspect of a tooth with the starting point being the round symmetrical platform of the fixture, in essence, attempting to “fit a square peg into a round hole”. This necessitates a supracrestal soft-tissue thickness of 3 to 4 mm to facilitate development of an appropriate emergence profile for the future crown. It is critical to consider this in the context of the biologic width associated with implant-supported restorations, which also typically varies from 3 to 4 mm. If the supracrestal soft tissue is thinner and the implant is placed at the bone crest, remodelling of the bone occurs to naturally re-establish the biologic width while simultaneously providing sufficient soft-tissue thickness for restorative purposes. Alternatively, clinicians will artificially provide space for reformation of the biologic width by placing the implant subcrestally. This can lead to additional bone remodelling such that an infra-bony defect develops around the implant that is then subject to further breakdown. Furthermore, this results in the abutment–implant interface being positioned subcrestally and it is well established that a zone of inflamed connective tissue can form in this area.[6] Thus, to provide sufficient space for the biologic width and tissue thickness for the emergence profile of the crown, a clinician could be creating a scenario that is highly susceptible to future crestal bone loss.

In this case report we describe a novel approach to replacing mandibular molars with a customised tooth-shaped implant that positions the abutment–implant interface supracrestally. The design of this implant will facilitate immediate placement in molar sockets, minimise the extent of crestal bone loss and yield highly aesthetic results.

Case report

A 70-year-old male physician with a non-contributory medical history presented with a compromised mandibular right first molar (#30) that was deemed to have a

Patent

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[1] Brunello G, Rauch N, Becker K, Hakimi AR, Schwarz F, Becker J. Two-piece zirconia implants in the posterior mandible and maxilla: A cohort study with a follow-up period of 9 years. Clin Oral Implants Res. 2022 Dec;33(12):1233-1244. doi: 10.1111/clr.14005. Epub 2022 Oct 31. PMID: 36184914.

[2] Glauser, R., Schupbach, P. Early bone formation around immediately placed two-piece tissue-level zirconia implants with a modified surface: an experimental study in the miniature pig mandible. Int J Implant Dent 8, 37 (2022). https://doi.org/10.1186/s40729-022-00437-z

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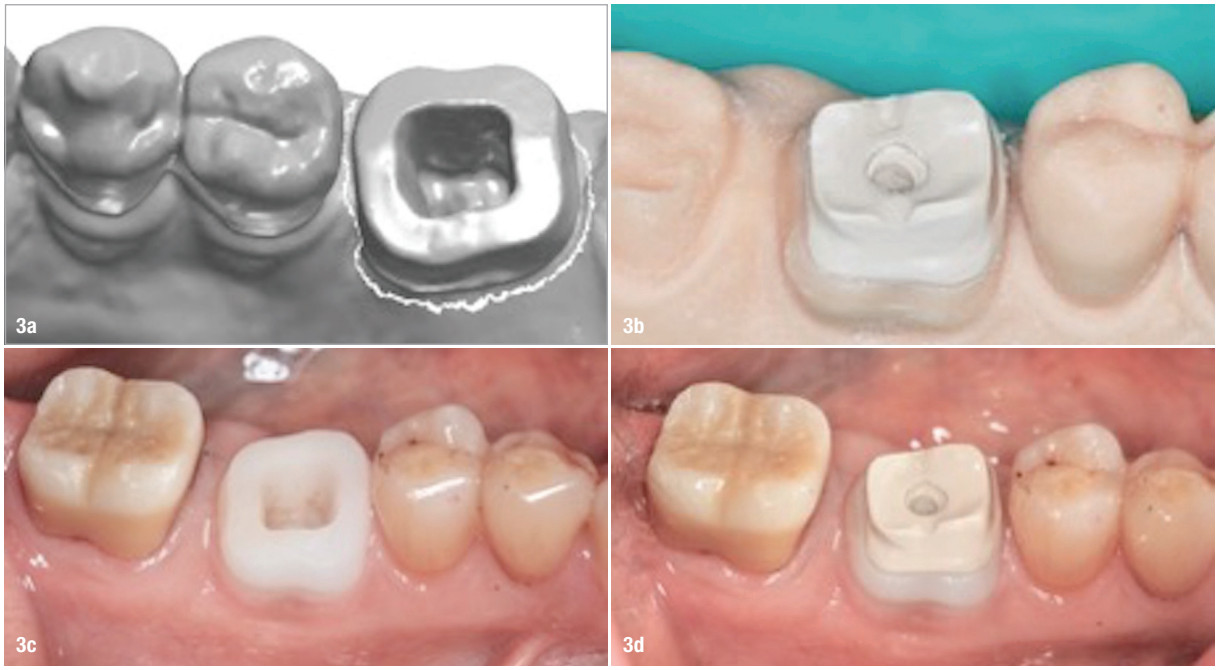


Figs. 3a–d: Fabrication of the abutment. Digital design of abutment **(a)**. Abutment milled from PEEK exhibiting adequate retention and resistance form for the future crown. A venting hole is present to allow complete seating of the abutment during cementation **(b)**. Implant–abutment interface prior to cementation of the abutment **(c)**. The abutment cemented in place **(d)**.

hopeless prognosis due to a failed endodontic procedure (Fig. 1a). He was offered three treatment options:

1. a removal partial denture,
2. a three-unit tooth supported-bridge from #29 through #31 or
3. an implant-supported crown.

After discussing the risks and benefits associated with each approach the patient decided on the third option. From casual discussions, he was extremely familiar with our work on the customised implant system and, understanding the experimental nature of the device, requested that one be used to replace his tooth. Informed consent was obtained for the procedure.

A CBCT demonstrated ample alveolar bone height and width for implant placement without the need for augmentation. The same CBCT scan was used to design and fabricate the implant construct from a zirconium dioxide block (yttrium-stabilised tetragonal zirconia polycrystalline) using computer-aided design/computer-aided manufacturing technology. The custom implant construct did not reproduce the entire natural tooth but did incorporate root-form and transgingival elements both of which mimicked the actual morphology of the patient's tooth. In contrast to traditional bone level implants, this design placed what would be considered as the implant–abutment interface in a supragingival position. Furthermore, the coronal aspect of the implant–abutment construct was not flat but was designed with slants in the mesiodistal and buccolingual dimensions to accommodate the natural ten-degree lingual angulation of mandibular molars. The gingival collar of the construct was polished while the transition zone and sub-osseous aspects of the implant were sandblasted with 50-micron aluminium oxide. The implant was cleaned, autoclaved, and maintained in a sterile package.

Local anaesthesia was administered via buccal and lingual infiltration injections adjacent to #30 using 4% Septocaine and 1:100,000 epinephrine. The tooth was sectioned buccolingually and the roots extracted in a minimally traumatic manner (Figs. 1b & c). The implant construct was press fit into the extraction site resulting in complete obliteration of the sockets (Fig. 1d). The hole in the coronal aspect of the construct was sealed with cotton and Cavit (3M ESPE). Postoperative instructions were reviewed with the patient as were prescriptions for Ibuprofen (600 mg, one tablet q6–8h PRN pain) and Amoxicillin (500 mg q8h for seven days). The patient tolerated the procedure well and was reappointed for a follow-up visit.

At the one-month follow-up visit, the patient denied any postsurgical complications and healing was progressing normally (Fig. 2a). The patient was seen six months later for insertion of a provisional restoration. The peri-implant soft tissues were found to be healthy and there was no radiographic evidence of bone loss around the implant. The old metalloceramic crown on #31 was removed to address recurrent caries and deteriorating margins followed by preparation for a full coverage crown. A digital

impression was taken of the implant at site #30 and prepared tooth #31 (Fig. 2b). The provisional crowns were fabricated out of acrylic using a block carving technique and cemented in place (Figs. 2c & d). An additional impression was made with the provisional restorations in place (Fig. 2e). The two STL files created from the digital impressions were merged into the 3Shape software (3Shape) to design the implant abutment, the implant-supported crown, and the conventional crown for #31. The implant abutment was digitally designed and milled from PEEK block material (Figs. 3a–c). After sandblasting and priming, the abutment was permanently cemented (Fig. 3d).

Digital versions of the final crowns were designed, and the files transferred to a milling machine (Figs. 4a–d). The restorations were milled from unsintered zirconium blocks (Fig. 5a), chromatised with liquid paint shade A4 (Fig. 5b) and subsequently sintered (Fig. 5c). Seven months post placement, the crowns were seated in the patient's mouth, adjusted, glazed extra-orally and polished. The crowns were then cemented with RelyX Unicem 2 (3M) resin cement. The restorations provided adequate support for the adjacent soft tissues and were aesthetically acceptable to the patient (Figs. 6a & b). A periapical radiograph was taken that confirmed the seating of the crowns and showed the intimate fit of the implant within the sockets of the extracted tooth (Fig. 6c).

Discussion

With appropriate case selection, immediate placement and restoration of implants is safe and yields predictable outcomes when replacing incisors, canines, and premolars. For numerous reasons, the same level of predictability has not been achieved in molar sites. To point out is the lack of adequate bone volume to achieve primary stability of the immediately placed implant. To address this issue, several groups have evaluated the use of customised one-piece implants mimicking the anatomy of natural teeth.[7, 8] The reported clinical outcomes have been mixed such that these types of fixtures are not a component of the armamentarium of modern-day implant dentistry.[9–11] Thus, this represents one clinical scenario that warrants development of alternatives to the implants currently on the market.

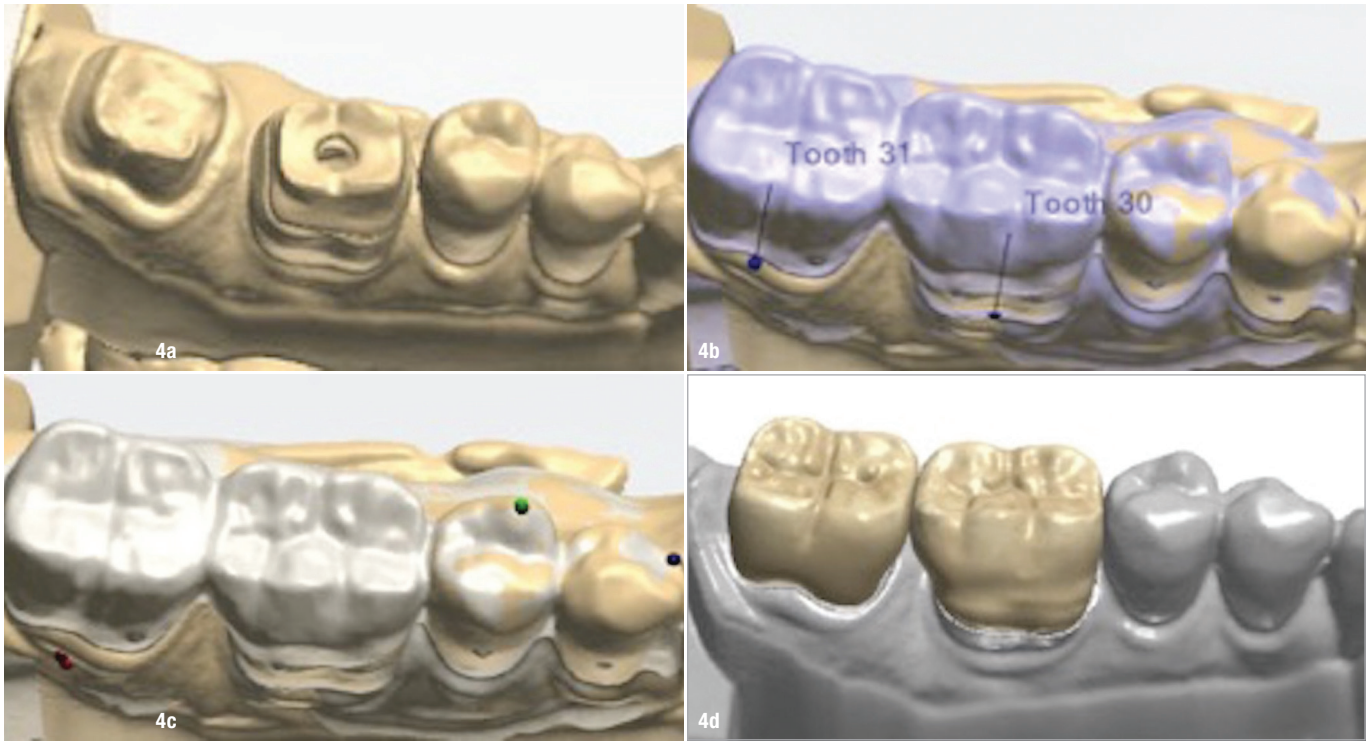
Recognising the potential benefits of customised root-form implants and appreciating the previously demonstrated deficiencies of the one-piece systems, a prototype of a unique two-piece customised implant system has been developed to be used for immediate placement following extraction of mandibular molars. Since this is a two-piece system, it avoids the necessity for immediate loading. Based on our fundamental knowledge regarding the wound healing response of alveolar bone and the overlying soft tissue following implant placement, the components were designed to minimise crestal bone loss while providing an environment that facilitates the fabrication of restorations with ideal emergence profiles. This case report describes the successful replacement of a compromised mandibular right first molar (#30) with this customised two-piece zirconia implant–abutment system.

The design of the implant and abutment incorporate several properties that should lead to quicker healing, reduced pre- and post-loading crestal bone loss, enhanced peri-implant soft-tissue health and improved aesthetic outcomes relative to conventional bone level implants. Since the shape of the implant is based on the anatomy of the patient's tooth, no site preparation is required for its placement. Minimally traumatic extraction of the tooth via a flapless approach is followed by press fitting the implant into the socket resulting in intimate contact with the adjacent alveolar bone allowing for quick and uneventful healing. By mimicking the shape of the natural tooth in the transition zone between the bone crest and gingival margin, the soft tissue is constantly supported in its natural configuration, greatly diminishing the likelihood of recession. Furthermore, the tissue level design of the implant positions the implant–abutment interface supracrestally permitting the biologic width to form on the fixture itself thereby mitigating the likelihood of crestal bone resorp-

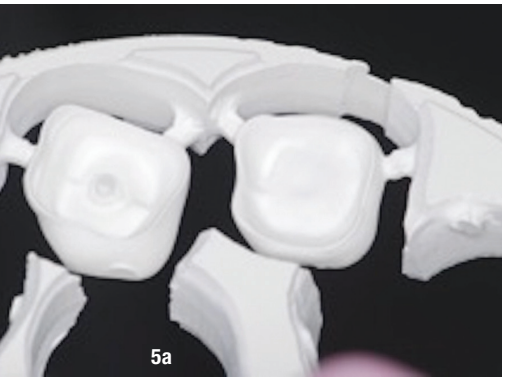
tion. Finally, the two-piece nature of the system permits a load-free period for osseointegration.

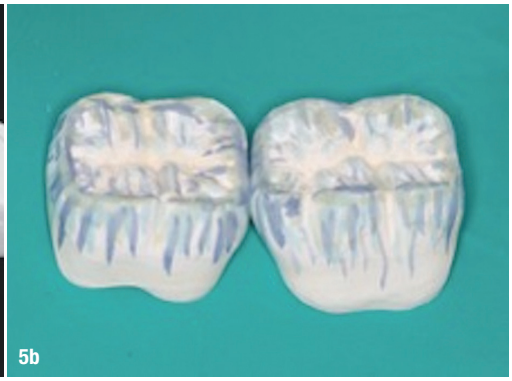
After careful consideration of the existing literature, different materials were chosen for fabrication of the implant versus the abutment. The implant itself was fabricated out of zirconia to take advantage of the multiple desirable properties of the material.[12, 13] Zirconia is a biocompatible material with the capacity to osseointegrate with surrounding bone. It possesses good mechanical properties including a high flexural strength and hardness, both of which are enhanced due to the thickness of the implant compared to the far narrower currently available implant designs. Recent research also suggests that biofilm formation occurs less readily on zirconia fixtures as opposed to titanium implants.[13] The abutment was fabricated from polyetheretherketone (PEEK), a high-performance thermoplastic material with a compressive strength similar to that of dentine and bone.[14] This property allows the material to dampen the effect of the occlusal load exerted on the implant once it is in function. Collectively, the combination of the biophysical and biomechanical properties of zirconia and PEEK should allow for long-term success of the implant and restoration.

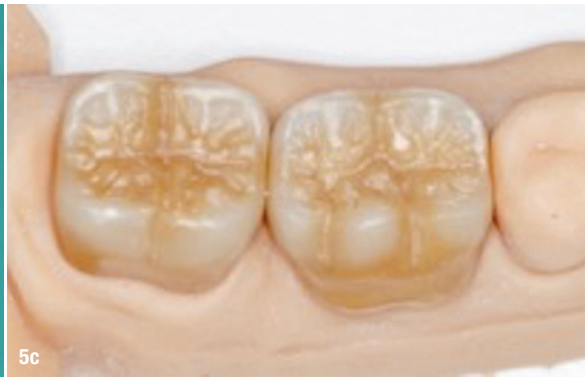
From the restorative perspective, the design of the prototype has numerous advantages over implants currently being used on a routine basis. First, the supracrestal position of the implant–abutment interface provides easy optical access for intra-oral scanning. Thus, it is possible to utilise digital impression techniques as opposed to more tedious and potentially recession-inducing analogue approaches. Second, because the supracrestal aspect of the implant mimics the shape of the tooth being replaced, the emergence profile can be developed without the need for excessive soft-tissue depth. With conventional implants, the emergence profile of the future crown must develop from the relatively narrow, round, and symmetric implant platform to a configuration that reproduces the morphology of the tooth at the gingival margin.[15] This asymmetric aspect of molars is much wider than implants in both the mesiodistal and buccopalatal/buccolingual dimensions. To properly support the adjacent soft tissues the laboratory technician must create an emergence profile that exhibits a very abrupt change in size and shape such that the crown ultimately resembles a "lollipop" as opposed to a natural tooth. The tooth-shaped design of the new implant allows for an anatomically correct emergence profile in association with a relatively shallow peri-implant sulcus. This is likely to facilitate biofilm removal by patients and therefore reduce the incidence of peri-implant mucositis or peri-implantitis. Third, eliminating screw-based retention of the implant-supported crown to cemented retention reduces the likelihood of common complications such as screw loosening and fracture. Of course, there is a current bias against cement-retained crowns because of their higher incidence of peri-implant soft-tissue disease. The position of the implant–abutment interface makes complete removal of excess cement predictable, negating this as an issue. Collectively,



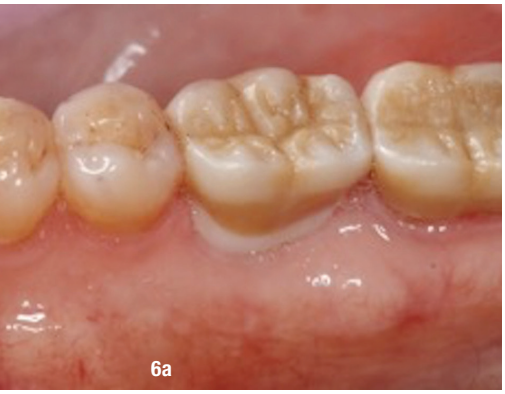
Figs. 4a–d: Design of final crowns. STL file of the implant abutment site #30 and prepared #31 **(a)**. STL file of scanned provisional restorations in place **(b)**. Merged files shown in a and b **(c)**. Digital version of final crowns **(d)**.

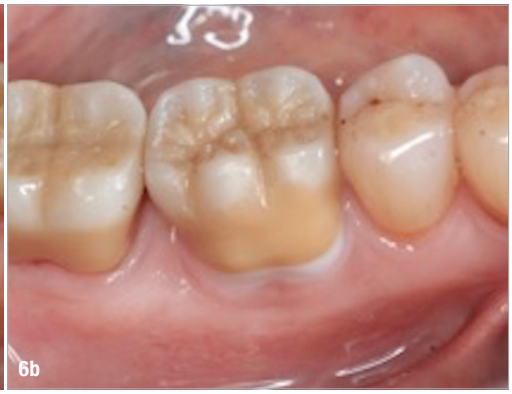


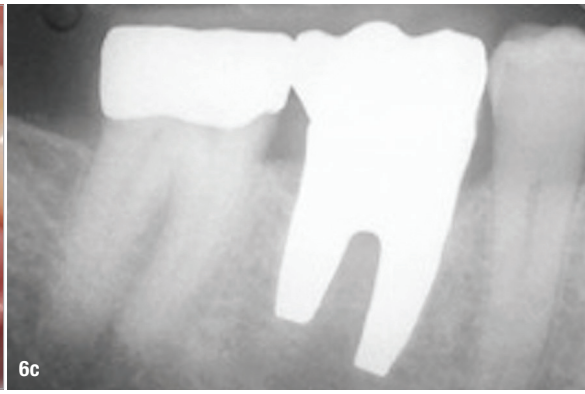




Figs. 5a–c: Production of final crowns. Final milled zirconium crowns prior to removal of nesting connections **(a)**. Wet staining of final crowns to achieve final shade of A4 **(b)**. Final monolithic zirconium crowns post-sintering **(c)**.







Figs. 6a–c: Insertion of final crowns. Buccal and lingual views, respectively, of final crowns cemented in place demonstrating form and colour **(a & b)**. Radiograph of cemented crowns demonstrating proper fit of crowns and adaptation of the implant to the bone of the extraction sockets **(c)**.

these properties render the technical aspects of restoring the prototype closer to those utilised for natural teeth as opposed to conventional implant-supported crowns.

Since Brånemark first introduced endosseous implants to the dental profession, much has been learned regarding the interrelationship between the device, surrounding bound and adjacent soft tissue. Furthermore, significant advances in our understanding of the biology of wound healing and osseointegration have been made over the last 20 years. By taking this information into consideration when designing the device described in this case report, it integrates concepts that distinguish it from previous iterations of implants mimicking the shape of natural teeth.[16,17]

Conclusion

The predictability of success in replacing teeth in unique situations, such as immediate replacement of molars, could be greatly enhanced through the utilisation of this customised implant. In the world of digital design and manufacturing we should not be limited by conventional concepts but strive to develop implant systems that more closely mimic the form and function of natural teeth.

Literature

contact

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