One of the drawbacks of dental implant treatment is the length of time from implant placement to definitive restoration. Patients with missing front teeth or who require a full-mouth implant restoration present substantial esthetic and functional challenges. Current provisional prostheses range from removable options such as a full or partial denture, a fixed option utilizing transitional mini-implants, or an immediately loaded definitive implant such as the “Teeth In A Day” procedure.1 The most commonly used denture material for a removable provisional prosthesis is polymethyl methacrylate (PMMA).2 The problems with removable acrylic dentures are the limitations in terms of strength and patient comfort.3 It is notoriously difficult for patients to comfortably wear the provisional prosthesis, especially after the immediate loss of their own dentition. The frequent fractures and poor patient compliance provide little value for both the practitioner and patient.3 The problem with a fixed transitional denture such as the “Teeth In A Day” implant procedure is that it requires chairside modification of the old removable denture to an immediately fixed implant-supported denture. This process tends to be very time-consuming and requires the patient to be present throughout the process. In addition, incidences of complications related to abutment screw loosening and acrylic fractures are common.1 Another fixed prosthetic option is the use of mini-implants that are placed between the definitive implants to support the provisional fixed dental prosthesis (FDP).4 Using mini-implants introduces more surgical and prosthetic steps to the
already-complicated implant process and, as a result, increases the risk of treatment complications and costs. There has been increasing interest in the dental community in the potential use of high-performance thermoplastic polymers of the polyacryl family such as polyether ether ketone (PEEK). This material can be used for processing in extrusion and injection molding or CAD/CAM milling processes. PEEK has a higher impact strength (5.3 kJ/m²) compared with PMMA (2.2 kJ/m²) and may be better suited for use as a provisional denture. In addition to its strength, it is light and flexible, with a density of 1,300 kg/m³. It has low water absorption and solubility values, high shock resistance, is resistant to abrasion, and is biocompatible. Moreover, PEEK can be bonded with dental composites, allowing for easy intraoral manipulation. Another mechanical advantage of PEEK is that it has a very low elastic modulus close to that of dental tissues, bone, and dentin compared with some conventional materials used, such as chromium cobalt, zirconia, and titanium. In the principle of removable prosthetics, prepared guide surfaces in natural dentition with intimate, firm, and continual contact with a prosthesis can stabilize a removable denture effectively. Similarly, the low elastic modulus of PEEK and the engagement to multiple guide surfaces of the healing abutment could be effective in stabilizing the provisional FDP. The aim of this study was to evaluate PEEK as a material for use in provisional FDPs that can be retained by reciprocated guide surfaces of hexagonal-shaped healing abutments during dental implant treatment.

MATERIALS AND METHODS

Twenty patients requiring teeth replacement with dental implants for partially and fully edentulous cases in the maxilla and mandible were selected. Twenty-three provisional PEEK FDPs were provided to patients based on esthetic and functional requirements during the transitional or healing phase of dental implant treatment. One hundred sixty-six external-hex implants each connected to a hexagonal-shaped healing abutment with an abutment screw were used in this study (Hexagonal Abutment Implant System, Biomedical Implant Technology; Fig 1). Currently, there is no treatment standard in the number of implants to replace missing teeth for long-term success. The minimum standard for the present long-term clinical follow-up study, in addition to the age and functional requirements of the patients, was to replace as many missing roots as possible rather than a tooth crown or a preconceived fixed number of implants per arch and without any bone grafting. The standard treatment protocol for all patients in this study was to be seen in week 2 after implantation for final impression and in week 3 for the insertion of the provisional PEEK FDP. Patients were seen as required through the healing period for complications and in week 12 for the insertion of a segmented fixed ceramo-metal prosthesis in the posterior and anterior regions. Descriptive statistics are presented as numbers for categorical variables and means ± SD for continuous variables.

Fabrication of the PEEK Framework (Fig 2)

Prefabricated internal-hex castable copings (Fig 1) and pattern resin were used to form the framework from the patient implant model. Using the lost-wax technique, the framework was invested (1700, Talladium) and burned out at 800°C. PEEK granules (Pekkton ivory, Cendres+Métaux) were pressed at 375°C to 380°C using a pressing machine (PEKK press, Cendres+Métaux).

Method of Attachment

One way to create a common path of insertion for a non-parallel implant arrangement (Fig 3) is to remove the mating components that are in obstruction. In Fig 3, the obstruction caused by the PEEK coping was selectively removed in the dental laboratory. Inversely, a common path of insertion can also be established by selectively removing the obstruction of the hex healing abutment intraorally without reducing the PEEK coping.

After the press procedure, each hex coping in the PEEK framework was independently evaluated with a healing abutment to ensure proper fitting. The reduced coping/framework was placed onto the final implant model to confirm adequate friction without interference or binding. The PEEK framework was sandblasted to create a rough surface to bond with tooth-shaded composite material after salination to the preindexed denture veneers, which contained both teeth and pink acrylic to provide the gingival esthetic. Veneering of the composites was prepared using an adhesive, visio. link, to combine the PEEK framework and veneers in
accordance with the manufacturer’s instructions (novo. lign Veneers and BioHPP, Bredent). Patients were recallled in week 3 after implantation and provided with the provisional PEEK FDP (Fig 4). In cases where patients had prosthesis dislodgment, screw retention was provided with abutment screws that were hand-tightened using the thread provision on the top of abutment screws and a preestablished screw recess in the castable coping (Fig 1).

RESULTS

Twenty-one custom provisional PEEK FDPs supported by 166 implants in 20 partially and fully edentulous patients were provided during the treatment period. The mean functional periods for maxillary and mandibular cases were 6.95 ± 0.84 months and 1.90 ± 0.62 months, respectively (Table 1). For maxillary cases, five were partially edentulous, and the remaining seven were fully edentulous patients, while these numbers in mandibular cases were four partially edentulous and five fully edentulous patients. Two provisional mandibular PEEK FDPs were excluded from calculations due to prolonged usage (over 2 years) with no reported complications and could no longer be considered a provisional prosthesis. All provisional PEEK FDPs functioned as intended through the healing phase with no fractures. Functional complications were seen mostly in partially edentulous cases due to unilateral occlusion, while esthetic complications were evenly distributed among all cases. Ten out of 21 prostheses had complications (Table 2). Three prostheses had complications that were esthetic in nature involving denture veneers debonding from the PEEK framework (Fig 5). Three out of nine partially edentulous cases with unbalanced occlusion required supplementary screw retention to prevent prosthesis dislodgment (Fig 6). Inadequate coping reduction may have caused excessive anterior gingival recession in one maxillary prosthesis (Fig 7). Three implants in separate patients did not osseointegrate, prolonging the use of the provisional PEEK FDP.

DISCUSSION

Traditional PMMA removable provisional dentures are inexpensive but provide limited value and poor patient compliance. FDPs are more beneficial, as they spread the load of mastication over all implants evenly, whereas removable prostheses can sometimes inadvertently overload individual implants. Another concern of FDPs is the immediate loading on dental implants.
during the treatment period. However, immediate implant loading has been shown to be a viable alternative to delayed loading that saves time for both the patient and dentist.\textsuperscript{14} There are few studies comparing the advantages of either removable or fixed provisional FDPs during dental implant treatment.\textsuperscript{15} However, the use of a weaker material like PMMA as a provisional prosthetic material is more prone to catastrophic fractures and complications during the provisional treatment period.\textsuperscript{2} The use of PEEK as a provisional prosthetic material is superior compared with PMMA because of PEEK’s overall higher compressive, flexural, tensile, and impact strength.\textsuperscript{6,8}

The application of osseointegrated implants to dentistry using traditional dental concepts presents many challenges, as dental implants are machined devices and not natural dentition. However, the present study abandoned fixed prosthetic concepts that require multiple natural teeth abutments to be made parallel for a common path of insertion for a splinted screw-retained prosthesis. Alternatively, a common path of insertion can also be created by selectively removing the undercut or obstruction of the healing abutment or coping from a geometric perspective (Fig 3), while conveniently adopting removable prosthetic concepts for retention by preparing guide surfaces on natural teeth.
The partial engagement of PEEK copings can effectively be retained by multiple reciprocated guide surfaces of the hexagonal healing abutments, similar to prepared guide surfaces in natural dentition (Fig 8).\(^{10,16}\) The low elastic modulus of PEEK is also an important factor in the retention of the provisional FDP. The process of selectively reducing the PEEK copings in a splinted framework can be precisely performed in the dental laboratory. The insertion of the provisional FDP can be in a single step without modifications or removal of the healing abutments. This method would circumvent the traditional way of attaching a provisional FDP chairside.

In edentulous cases with balanced occlusion, the opposing guide surfaces of the healing abutments allow the provisional FDP to be effectively retained without screw retention. However, in most partially edentulous cases with unbalanced or unilateral occlusion, additional screw retention was needed to prevent frequent dislodgment, especially when there was no element of cross-arch stabilization. There was no reported prosthetic retaining screw loosening due to the partial engagement of the PEEK coping to the hexagonal abutment protecting the retaining screw from occlusal forces. The screw-retention provision is incorporated in the abutment screw and its corresponding castable copings providing supplementary retentive options for the prosthesis (Fig 1). There may be two reasons for the absence of PEEK framework fractures in this study: (1) PEEK’s relatively high compressive and impact strength; and (2) a higher number of implants placed. Patients with fully edentulous restorations had an average of 11.2 implants per arch, and in partially edentulous restorations, the average was four contiguous implants per site. The purpose of this study was to utilize the reciprocated guided surfaces of the hexagonal healing abutment for frictional retention of the provisional PEEK FDP. With replacement of missing roots, the supported distance between abutments or implants from center to center would not exceed 6 mm. In cases when one or two implant sites required healing prior to implantation, the supported distance between implants would be 12 mm apart; no cantilever was used as a rule. The provisional prosthesis needs to provide esthetic and function for both partially and fully edentulous cases, regardless of the presence or absence of opposing natural dentition. A full-arch provisional prosthesis can function adequately with the advantage of cross-arch stabilization and the retention provided by the guide surfaces of the healing abutment without screw retention. In partially edentulous restorations, additional screw retention will reduce the incidence of prosthetic dislodgment.

The functional period of the provisional PEEK FDP varied in maxillary and mandibular cases. There were frequent implant failures in maxillary cases because of poor quality and quantity of bone.\(^{17,18}\) The time required for healing and reimplantation of new implants extended the functional period. For mandibular cases, implant osseointegration is more predictable, and the functional period of the provisional PEEK FDP is often shorter. However, two patients in this study with provisional mandibular PEEK FDPs could not be considered as provisional prostheses and were excluded from calculations, as they continually postponed the insertion of their definitive prosthesis over an unreasonable length of time without reported complications. This raises the question of whether the provisional PEEK FDP can become a definitive prosthesis. Clinically, a provisional FDP would also provide a functional try-in period for the evaluation of prosthetic parameters, resulting in the fabrication of a more accurate definitive prosthesis. The use of hexagonal-shaped healing abutments can provide indexing to the internal geometric features of the implant housing without the need of an additional impression.
ments can provide adequate retention and resistance guide surfaces of the hexagonal-shaped healing abutments. Accordingly, such a setup could be long-term retention and the method of selectively reducing the part of the PEEK coping can precisely create a common path of insertion regardless of the number and trajectories of hexagonal healing abutments or implants.

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**REFERENCES**


**CONCLUSIONS**

Within the limitations of this study, PEEK can be a suitable material for use in provisional FDPs during dental implant treatment. Prosthetic complications were frequent but were resolved intraorally. The reciprocated guide surfaces of the hexagonal-shaped healing abutments can provide adequate retention and resistance in edentulous FDPs. However, in partially edentulous prostheses without cross-arch stabilization, supplementary screw retention was required. The method of selectively reducing the part of the PEEK coping can precisely create a common path of insertion regardless of the number and trajectories of hexagonal healing abutments or implants.