



## Review Article

## Contemporary treatment modalities for definitive rehabilitation of acquired maxillary defects – A review

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## ABSTRACT

Various techniques have been described to restore acquired maxillary defects. The aim of this paper is to review the contemporary treatment modalities that have been explored to rehabilitate and reconstruct partial or complete maxillectomy in dentulous and edentulous patients. MEDLINE/PUBMED search was conducted for dental literature published from January 2000 to December 2018. Literature study revealed various methods and materials used to treat patients with acquired maxillary defects. These include modifications in method and materials used for the fabrication of conventional obturators (using precision and semi-precision attachments, telescopic copings, magnets, silicone based materials, titanium and its alloys, PEEK, thermoplastic resin); implant-supported obturators supported on conventional, zygomatic and pterygoid implants using different attachments (ERA, magnet, bar attachment, locator, ball attachment); use of CAD/CAM technology for presurgical planning and fabrication of obturator prosthesis; surgical reconstruction with microvascular free tissue flaps; and bone engineering. Significant attention has been devoted to refining current methods and developing better methods to successfully rehabilitate maxillectomy patients. The use of osseointegrated implants, newer prosthesis materials, advanced laboratory procedures, inclusion of CAD/CAM technology, advances in surgical reconstructive techniques and tissue engineering has revolutionized the traditional treatment options.

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### 1. Introduction

Rehabilitation of acquired maxillary defects is a daunting task. They are a result of infections, trauma, inflammatory and neoplastic diseases necessitating surgical resection.<sup>1</sup> Spontaneous loss of teeth, distortion of intra-oral anatomy, facial and functional impairment can negatively affect the patient's quality of life. Effective treatment modalities are necessary to promote oral function and psychological well-being. Factors influencing successful rehabilitation include, teeth present, muscular control, nature of defect and supporting structures, radiation therapy and disease recurrence.<sup>2,3</sup>

The aim of the present work is to review the advancements made in the field of rehabilitative procedures for acquired maxillary defects.

### 2. Materials and Methods

MEDLINE/PUBMED and Google Scholar search was conducted for articles published from January 2000 to December 2018 to identify data focusing on definitive rehabilitative procedures for patients with acquired maxillary defect. Key words or phrases included “acquired maxillary defects,” “surgical maxillary reconstruction,” “maxillectomy,” “implants,” “obturator”.

Titles and/or abstracts of articles identified through the electronic searches were reviewed and appropriate articles

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were subjected to inclusion and exclusion criteria. A manual search of the reference lists of selected articles was undertaken and literature that was judged relevant was critically reviewed.

Criteria for considering studies for this review are given below

### 2.1. Inclusion criteria

1. Management of acquired maxillary defect.
2. Management of hard palate defects in partially dentulous and edentulous patients.
3. Peer-reviewed articles in English language.

### 2.2. Exclusion criteria

1. Management of extra-oral defects including face, eyes and nose.
2. Management of soft palate defects.
3. Fabrication of surgical and interim obturator.

## 3. Results

The selected articles concentrated on fabrication of conventional definitive obturator and implant-supported obturator, surgical reconstruction followed by prosthodontic rehabilitation, application of CAD/CAM technology and bone tissue engineering.

## 4. Discussion

### 4.1. Definitive obturator

Definitive obturators are usually advised in smaller maxillary defects due to the functional and aesthetic challenges faced in larger defects. They permit immediate restoration of function with minimal surgical intervention and inspection of the defect area for recurrent lesions. They facilitate oral hygiene procedures and are economical.<sup>2,4</sup> Nonetheless, certain disadvantages have been cited, such as, non-permanent closure of the oral and sinonasal communications, arduous placement in patients with trismus and extensive defects, need for frequent adjustments and associated with a negative psychosocial stigma.<sup>5,6</sup>

#### 4.1.1. Conventional definitive obturator

Restoration of maxillectomy defects demand varied modifications in prosthesis fabrication, to make them lighter and well-tolerated by the patient. The size and location of the acquired defect, the quantity and integrity of the residual maxilla, presence of retentive scar band, muscular control and the nature of remaining abutment teeth play a major role in the construction of the prosthesis.<sup>2,7,8</sup> These factors directly influence the retention of the obturator and the possible treatment success. Failure to follow the necessary guidelines can lead to premature loss of abutment

teeth, chronic irritation of soft tissue and loss of prosthesis retention.<sup>9</sup>

Literature suggests the use of various retentive aids for the construction of conventional obturator to improve retention and oral function, for example, extension into nasal aperture space,<sup>10</sup> bar-clip system,<sup>11,12</sup> ball attachment,<sup>11,13</sup> magnets,<sup>14,15</sup> orthodontic wire clasps,<sup>15</sup> telescopic crowns<sup>16</sup>, retentive dowels on framework,<sup>17</sup> swing-lock attachment,<sup>18</sup> Herbst appliance (moving orthodontic tubes) with orthodontic Forsus<sup>TM</sup> Fatigue Resistance Device (OFFRD),<sup>19</sup> Preci-Vertex precision attachment on ceramo-metal crowns<sup>20</sup> and use of springs to engage resilient liner material with the hollow acrylic obturator.<sup>21</sup>

Titanium and its alloys have been used to fabricate light obturator framework.<sup>22,23</sup> Various spacer materials have been suggested to improve hollow bulb fabrication such as acetate,<sup>24</sup> modeling clay with tin foil<sup>25</sup> and salt with cellophane.<sup>25</sup> Moreover, newer materials have been suggested for bulb fabrication such as, thermoplastic resin,<sup>26</sup> thermoplastic splint material,<sup>27,28</sup> Polyetheretherketone (PEEK) material<sup>29</sup> and flexor material.<sup>21,23</sup> Simplified laboratory procedures have been proposed for hollowing of the obturator, such as: 1) processing the obturator in separate parts and then fusing them together with resin material or anchoring systems,<sup>4,12,30</sup> 2) incorporation of spacer within the bulb to form a hollow cavity. Spacer recovery is done by make an opening in the processed obturator<sup>31,32</sup> and 3) fabrication of hollow bulb templates which are incorporated in the obturator bulb.<sup>25,27,28</sup>

#### 4.1.2. Implant-supported obturator

A significant number of patients have difficulty in retaining the obturator prosthesis due to absence of teeth and/or extensive defect size. This necessitates the utilization of osseointegrated dental implants as a framework for the overlying prostheses. Implant-supported rehabilitation promotes increased retention of the removable prostheses and reduction in the load placed on the vulnerable soft tissues.

Implant survival is significantly influenced by the experience of the surgeon, bone quality, and implant related factors including primary stability. Moreover, factors such as the patients' general and oral health and personal habits affect implant survival. Even though radiation therapy can affect the success of implants, they remain a functional option for rehabilitation of maxillectomy patients.<sup>33,34</sup> The use of hyperbaric oxygen therapy (HBO) has resulted in improved osseointegration of implants placed in radiated bone. However, HBO may not always be needed for implantation following radiotherapy if not available.<sup>35</sup> Implants are contraindicated in the following patients: 1) systemically compromised, 2) small defects with sufficient remaining dentition, 3) recurrent disease and 4) non-compliant.<sup>36</sup> Implant-supported obturator facilitates oral

hygiene procedures. They are less expensive than fixed prostheses and can better compensate for any remaining defects following soft tissue reconstruction.<sup>36</sup>

4.1.2.1. Conventional dental implants. The type and distribution of implant anchorage is dependent on the extent of the surgical resection and the available bone. At least four wide, long regular dental implants placed in a non-linear configuration are recommended. Implants should be placed in the residual alveolar bone rather than the bone surrounding the defect site. Favorable implant positions include premaxilla, tuberosity and posterior alveolus. The implant platform should be leveled as close as possible to the soft tissue of the residual defect.<sup>37,38</sup> Reduction of cantilever stresses, rigid fixation of prosthesis, cross-arch stabilization by splinting all the implants and close adaptation with maximal lateral extension of obturator minimizes technical and biological complications.<sup>37,38</sup> However, complications with prosthetic superstructures such as screw loosening and screw fractures are frequently encountered.<sup>39</sup>

4.1.2.2. Zygomatic implants. Zygomatic implants are used for prosthetic rehabilitation of extensive defects, in absence of adequate maxillary alveolar bone and in the presence of a minimum of 15 mm of zygomatic bone support.<sup>40</sup> Implant position and angulation should provide favorable AP spread. Bilateral defects demand the placement of two zygoma implants bilaterally. Unilateral defects without teeth in the unaffected side need one or two zygoma implants in the affected side and 2 or 3 regular dental implants with long AP spread in the unaffected side.<sup>40</sup> Boyes-Varley et al.<sup>41</sup> advocated immediate implantation of zygomatic implants following ablative surgery to circumvent the need for a vascularized flap and its associated inconveniences. In addition, this protocol allows implant osseointegration prior to postoperative radiotherapy. He suggested the fabrication of fixed-removable overdentures or fixed prostheses placed over definitive cast titanium superstructure, with and without separate obturators. Mittal et al. suggested the use of single-piece zygomatic implants to provide retention and support for an acrylic resin obturator and to alleviate osteocutaneous grafting procedure in a large maxillary defect.<sup>42</sup>

Limitations associated with zygomatic implants include unavailability of bone, restricted intra-operative vision, anatomic complexity and variability of zygoma bone.<sup>43</sup> Also, overloading leverage in large defects, overgrowth of local soft tissue preventing abutment connection, sinus infections, facial pain, damage to surrounding structures and positional errors can adversely affect the success rate.<sup>44</sup> Computer-guided implantation surgery using Computed tomography (CT) scan-based navigation system has been suggested for accurate positioning of the zygomatic implants.<sup>45</sup> Also, the fabrication of stereolithographic

surgical guides based on cone beam computed tomography (CBCT) data and presurgical implant planning using 3-dimensional (3D) implant planning software has been suggested for implant surgery.<sup>41,43</sup>

4.1.2.3. Pterygoid implants. These implants are anchored in the pterygoid plate through the maxillary tuberosity. They follow an oblique mesiocranial direction and end either in the pterygoid or scaphoid fossa of the sphenoid bone.<sup>46</sup> Advantages of using pterygoid implants include 1) Placement under local anesthesia, 2) Good anchorage due to appropriate density of bone and 3) Osteotomy preparation using osteotomes and surgical drills, which help to save bone, reduce surgical risks and minimize potential injury to vital structures.<sup>47</sup> The success rate of pterygoid implants has been recorded to be 97.05% at one year follow-up.<sup>48</sup> However, surgical complications have been reported, such as, trismus, misplacement of implant and bleeding.<sup>46</sup>

4.1.2.4. Attachments for implant-supported obturator. Literature describes different implant abutments and superstructures that are suitable retentive elements for an implant-supported obturator. These include locator,<sup>46</sup> magnet,<sup>49</sup> bar-clip system<sup>35,43</sup>, extra-coronal resilient semi-precision attachment (ERA) attachment<sup>50,51</sup> and ball attachment.<sup>50,52</sup>

Bidra et al.<sup>46</sup> suggested the use of Locator abutments (Locator, Zest Anchors, Escondido, Calif) supported on pterygoid implants. Al-salehi et al.<sup>49</sup> reported the fabrication of a magnet-retained and milled bar-retained implant-supported overdenture. Rare earth alloy neodymium-iron-boron (Nd-Fe-B) magnet (M3 Maxi Magnet, Magnacap) and two CEKA (M2:RE 0795 TI, CEKA, Antwerp, Belgium) spring pins were incorporated in the intaglio surface of the obturator. Magnets are routinely used to attach dental prostheses to divergent osseointegrated implants. Milled bar attachments are preferred to conventional cast bar attachments since conventional bars are associated with high risk of misfit in long-span, implant-retained reconstructions.<sup>35</sup> Splinting of implants with milled bar, having a short cantilever design and provision of an accurate metal framework connecting all implants tremendously minimizing the risk of implant overload.<sup>43</sup> Mertens et al.<sup>53</sup> suggested the use of CAD software to design a one-piece, cross-arch milled cobalt-chrome bar superstructure in order to increase the number of retentive elements and to achieve broader support. Chhabra et al.<sup>52</sup> suggested the use of Dalla bona ball attachment. Noh et al.<sup>43</sup> suggested the use of CAD/CAM technology to mill a titanium bar on customized abutment with a housing for magnetic attachments on the milled bar. Leles et al.<sup>50</sup> suggested the use of castable O-ring attachments (Conexão Sistemas de Prótese, São Paulo, Brazil) and an ERA abutment (Sterngold Implamed, Attleboro, MA) attached to a castable bar. The O-ring and ERA attachments were selected due to limited vertical space

provided by the implant position, the custom bar design and the need to create a harmonious path of insertion for all attachments. Kapadia et al.<sup>51</sup> suggested a Hader bar pattern (PREAT Corp., Grover Beach, CA) on the multiunit abutments, which incorporated an ERA mesially (to act as a stress breaker) and a recess distally (to allow insertion of a vertical Shark fin-projection of the titanium framework, creating resistance to rotation into the defect).

#### 4.2. CAD/CAM technology in management of acquired maxillary defects

Computer-aided design/computer-aided manufacturing (CAD/CAM) technology promotes better presurgical preparation, decreases intraoperative time, increases accuracy of reconstruction and produces superior outcomes especially in cases with limited visibility and anatomic complexity.<sup>54</sup> It can also be used to design, develop and fabricate an obturator.

For obturator fabrication, 3D imaging techniques such as CBCT allows acquisition of radiologic data. CAD processing allows 3D reconstruction, boundary creation, shape design and planning of implant attachments. Digitally scanning, surveying and designing the framework on the master cast using model scanner and computer software is also possible. CAM technology (Stereolithography) can be used to manufacture a resin positive mould representing the defect shape, which can aid in final impression procedures for the obturator.<sup>55,56</sup> It can also be used to add resin to produce a sacrificial pattern of the metal framework of the RPD which further undergoes conventional casting procedures.<sup>57</sup> CAD/CAM technology allows precision in designing the framework, simplifies laboratory procedures and allows availability of digitally saved data for reproduction of the prosthesis. Nonetheless, such technology is highly expensive. The use of polyetheretherketone (PEEK) has also been suggested for fabrication of obturators; however, no long-term clinical studies have been published.<sup>58</sup> In addition, dynamic navigation real-time tracking systems can be used to transfer virtual presurgical planning to the surgical sites. However, these tracking systems are sophisticated and increase cost.<sup>43</sup> Alternatively, Stereolithographic surgical guides made using CAD/CAM technology promote accurate implant placement, thus, improving dental alignment and aesthetic contour. During surgical reconstructions, the harvested bone graft can be shaped extraorally on a three-dimensional printed model of the recipient site, prior to intraoral adaptation, thus increasing bone-to-bone contact and reducing complications.<sup>59</sup>

Rapid prototyping uses an additive process of building an object in layers defined by a digital model that has been virtually sliced. It includes procedures such as stereolithography, which, produces 3D objects by curing photocurable liquid polymers under a computer-guided

laser in a layer-by-layer fashion and Thermojet printer (3D Systems), which, operates as a network printer and uses wax as the building material.<sup>60,61</sup> The 3D planning software allows the user to interact virtually with the model permitting all the necessary adjustments of the model before tooling the final product. However, the limitations include complicated machinery, high cost and special expertise to operate the machinery.

#### 4.3. Surgical reconstruction

The goals of surgical reconstruction include, 1) immediate single-stage closure of the defect, 2) preserve normal speech, swallowing and velopharyngeal function, 3) obliterate postoperative dead space, 4) minimize the inconveniences of removable obturators, 5) provide support for facial soft tissue and orbital contents and 6) create a stable pre-prosthetic framework for implant reconstruction and/or obturator fabrication.<sup>5,62</sup>

However, the prime disadvantage of surgical reconstruction is that it does not allow direct inspection of the resection cavity, in case of postoperative recurrence. Also, it involves complex procedures needing higher surgical expertise, longer operating time and recovery time. It requires proper patient selection based on the patient's medical condition, tolerance to donor site morbidity, ability to undergo multiple revision surgeries and economic status. Moreover, such patients may be at a higher risk of systemic complications.<sup>63,64</sup> Donor site morbidity is commonly associated with free flap reconstruction, such as, gait disturbance and herniation of abdominal contents (iliac crest flap), loss of normal hand function (radial forearm flap) and inability to rotate the shoulder (scapular flap).

Surgical reconstruction has seen tremendous advances in locoregional and microvascular surgery.<sup>65</sup> Decision making on choice of tissue flap is dependent on the size of the defect, integrity of the remaining dentition and the type of prosthodontic rehabilitation following reconstruction.<sup>66</sup>

Small localized defects involving posterior maxilla and palate are usually restored with local flaps and regional pedicled flaps with or without free bone grafts, such as, buccal pad of fat, Temporalis myofacial, Sternocleidomastoid, and Pectoralis Major flap. However, they are associated with limitations such as less tissue bulk, shorter pedicle length, lack of ability to allow osseous reconstruction and can lead to contraction and obliteration of sulcus, making dental rehabilitation difficult.<sup>5,65,67</sup>

Split skin grafts have also been used to repair small to medium sized defects, however, they do not possess an inherent blood supply and need to re-establish vascular supply and drainage from the recipient bed.<sup>66</sup> Tissue from the buccal mucosa, floor of the mouth and lateral tongue are frequently harvested.

Larger maxillary defects require either free vascularized soft tissue flaps combined with free bone grafts or

vascularized osteomyocutaneous flaps (free bone flaps) followed by implant placement.<sup>68</sup> Microvascular free flap surgery allows the transfer of muscle, connective tissue, skin and bone to recipient sites, as opposed with local or regional myocutaneous flaps.<sup>6</sup> This technique allows various donor tissue types to be used and can be customized to match the defect.

Free soft tissue flaps include radial forearm fascio-cutaneous flap (RFFF), rectus abdominis flap, anterolateral thigh flap and deep inferior epigastric artery perforator flap (DIEP).<sup>5,67</sup> These flaps contain long pedicle length making vascular anastomosis in the neck easier. However, they are unable to provide bony support for facial structures and implant placement. Therefore, these flaps are usually used in combination with non-vascularized bone grafts or titanium mesh.<sup>69,70</sup> When a combination of non-vascularized bone grafts and titanium mesh is used, it is known as the tissue prefabrication technique. In this technique, a folded custom-made titanium mesh tray with crushed autologous bone particles is interposed between 2 layers of flap.<sup>71</sup>

Abundant literature is present on the use of free bone flaps for maxillary reconstruction. Free bone flaps include fibula free flap (FFF)<sup>67,72</sup>, scapula flap,<sup>73</sup> radial forearm,<sup>74</sup> iliac crest flap systems.<sup>5,68,75</sup> These flaps provide support to the adjacent facial structures and provide a stable palato-alveolar base for the prosthesis. They also permit permanent closure of the defect site and the oronasal communication<sup>6</sup> and allow the placement of dental implants for an implant-retained prosthesis.<sup>76</sup> Radial forearm free flap and scapula free flap are most commonly used followed by implantation of osseointegrated implants in the reconstructed site.<sup>70,71,73,74,77–79</sup> The subscapular system of flap possess long pedicle length, large amount of soft tissues and has minimal donor site morbidity. These offer the greatest versatility in flap reconstruction since all components of the flap can be rotated independently of each other and facilitate in setting. Also, shapes of the palate and the scapular tip have been found to be similar.<sup>77</sup> Radial forearm free flap is commonly used due to its versatility and reliability.<sup>78</sup> It has pliable skin paddle, which is relatively hairless. Moreover, it has adequate long vascular pedicles, can provide sensibility by including lateral antebrachial nerve into the flap, controlled mobility, less bulky and conforms to complex shapes of the defect cavity. However, radial forearm flaps are known to develop a hematoma, necessitating re-exploration surgeries. Iliac crest free flap are usually indicated in patients undergoing total maxillectomy with orbital preservation. However, this flap has excessive bulk, restricted soft-tissue mobility in relation to the bone, short pedicle length and donor site morbidity.<sup>80</sup>

#### 4.4. Prosthetic rehabilitation following surgical reconstruction

Retention of conventional dental prostheses in surgically reconstructed sites may be compromised due to the bulk and mobility of the flap tissue. Moreover, growth of hair and excessive flap thickness may interfere with the fabrication procedures of the prosthesis. This necessitates planning the prosthodontic rehabilitation of the patient prior to surgery.<sup>80</sup> The use of osseointegrated implants in association with these reconstructive techniques has optimized functional rehabilitation and retention of maxillary obturators. A good primary stability of the implant in the grafted site is very crucial for the success of the secondary reconstruction. Otomaru et al.<sup>81</sup> reported a case of implant-retained obturator that was fabricated with a custom abutment and magnetic retention, following reconstruction with FFF. This was done since the conventional obturator fabricated after surgery was unsatisfactory. Customized abutment copings are used to connect the implants, so as to prevent implant loss and they allow variations in size and shape, so as to prevent mobility and rotation of the obturator. Magnet attachment system is used as an overload breaking mechanism, since the magnet and keeper are forced out of the joint when prosthesis is subjected to high occlusal forces. Mertens et al.<sup>79</sup> reported a case series of patients undergoing primary reconstruction with scapula free flaps, followed by prosthetic rehabilitation with fixed prosthesis and implant-retained dentures (milled CAD/CAM fabricated bars, ISUS, Dentsply, Hasselt). He proposed that the decision for fixed versus removable rehabilitation was based on the soft-tissue situation (scarring), the ability to achieve good oral hygiene (mouth-opening) and the required vertical height of the prosthesis.

Fixed-hybrid or a bar-retained prosthesis is commonly advised for rehabilitation of acquired maxillary defect using osseointegrated implants. Nevertheless, milled bar-retained removable prosthesis are more commonly recommended as compared to fixed-hybrid prosthesis.<sup>43,50,53</sup> In cases of presence of an oroantral/oronasal communication, a combination fixed-hybrid prosthesis and obturator or bar-retained prosthesis has been suggested.<sup>40</sup> Most often it has been reported that, following primary reconstructive surgery, bone augmentation procedures and additional soft-tissue surgery may be necessary prior to prosthetic rehabilitation.<sup>79</sup>

#### 4.5. Bone tissue engineering for maxillectomy defects

Tissue engineering involves regeneration of new tissue with biologic mediators.<sup>67,82</sup> Recent research has reported the use of stem cells, growth factors and a synthetic scaffold as alternative method for defect repair, in an attempt to alleviate the disadvantages encountered with surgical reconstruction. Melville et al.<sup>83</sup> suggested the use of radial

forearm fasciocutaneous flap combined with an immediate tissue engineered graft using avascular allogenic bone, bone morphogenetic protein and bone marrow aspirate concentrate to reconstruct a maxillary alveolus. Although this technique allows precise contouring of the bone into the correct anatomic position, it still involves the undesirable outcomes of donor site morbidity. Recent research efforts are focused on synthetic scaffolds, suitable carrier agents for BMP, the use of growth factors and signaling molecules. The accessibility of equipment and expertise for stem cell harvesting and culturing is limited and a long delay is associated with the completion of the reconstruction. Thus, further research is necessary, before bone tissue engineering can be effectively applied in a clinical setting.

#### 4.6. Quality of life studies

Recent quality of life studies (QOL) suggest that there is no statistically significant difference between obturator and free flap groups in terms of language, mastication, swallowing and correlated depression.<sup>84–86</sup> However, it was noted that obturator patients experienced more soreness and pain, were less satisfied with the denture function and were more self-conscious.<sup>84</sup> Nonetheless, based on the present literature, it can be concluded that there is a limitation for the use of obturator prosthesis in patients with trismus, irradiated patients and in patients with large maxillary defects.<sup>6,87,88</sup> It was reported that as the defect size increased, there was a reduction in the speech and swallowing outcome with the use of obturators.<sup>87</sup> Also, it was noted that irradiated patients experienced dryness and soreness of the mucosa, thus, presenting with pain and difficulty in tolerating the prosthesis.<sup>89</sup>

Restoration with microvascular free flaps has revolutionized reconstructive surgery permitting primary, single-stage reconstructions.<sup>5,62–81</sup> However, surgical reconstruction is not indicated in patients with maxillary cancer, where periodic surveillance of the cavity for disease recurrence is mandatory. On the other hand, advanced imaging modalities like CT, Magnetic Resonance Imaging (MRI) scan and the use of these modalities as diagnostic aids, are supporting the adoption of surgical reconstruction followed by secondary reconstruction with dental implants as a reliable method in cancer patients.<sup>67</sup>

#### 5. Conclusion

Recent developments in rehabilitative techniques for acquired maxillary defects has ensued improvements in the quality of life. Reconstructive and rehabilitative techniques involving osseointegration, microvascular free tissue transfer and CAD/CAM technology have resulted in improved functional and aesthetic outcomes.

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#### 7. Conflict of Interest

None.

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