Secondary Stabilization of Maxillary M-4 Treatment with Unstable Implants for Immediate Function: Biomechanical Considerations and Report of 10 Cases After 1 Year in Function

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Purpose: Primary stability of dental implants, particularly when they are placed into immediate function in the maxilla, has been thought to be required. An alternative to primary stability is secondary stabilization, which can be obtained by a four-implant distribution pattern using 30-degree angulations for all four implants in the so-called “M-4” treatment scheme in combination with cross-arch stabilization from a prosthesis. If successful, the use of these two measures brings into question whether or not primary stability is required for immediate function in the maxilla.

Materials and Methods: Patients were treated with the M-4 implant scheme with immediate function, despite the instability of at least one of the four implants. Instability was defined as less than 15 Ncm of insertion torque and palpable mobility, and an average anteroposterior spread of 15 mm between each implant was sought. The patients were followed for 1 year. Results: Ten patients were treated with a total of 40 implants. Composite insertion torque of the four implants was less than 100 Ncm in half of the patients; the average anteroposterior spread was 15.6 mm. After 1 year, no implants had been lost, and bone levels around all implants were at or near operative levels. There were no failures of provisional or definitive prostheses. Conclusions: M-4 distribution of implants with an average of 15 mm of anteroposterior spread and cross-arch stabilization did not require that all four implants had high insertion torque; in fact, all mobile implants stabilized and osseointegrated under these conditions. ORAL CRANIOFAC TISSUE ENG 2012;2:294–302. doi: 10.11607/octe.0040

Key words: All-on-Four, anteroposterior spread, composite insertion torque, cross-arch stabilization, immediate function maxilla, insertion torque, M-4, primary stability, secondary stabilization

To proceed with immediate loading when using four 30-degree tilted maxillary implants in an M-shaped configuration (M-4), a scheme that takes advantage of paranasal bone to gain at least 15 mm of anteroposterior (A/P) spread, primary stability is generally considered essential.1–4 However, primary stability of all four implants is not always required because of the secondary stabilization obtained from the intrasosseous M-4 configuration itself, as well as cross-arch splinting from the provisional restoration.5

It has been previously proposed that for immediate function there must be not only adequate insertion torque but adequate bone-to-implant contact to proceed to immediate loading.6,7 For single-tooth immediate function, this is reported to be 6 mm of circumferential bone, a substantial quantity that is rarely available in the atrophic maxilla.7

For a four-implant scheme in which there is minimal bone-to-implant contact for all four implants, a composite insertion torque has been suggested to help the clinician establish a quantitative threshold for proceeding to immediate function.1 This threshold has been clinically determined to be 120 Ncm, with a minimum of 30 Ncm per implant.1,8 However, the current

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report details the use of individual implants well below 30 Ncm in insertion torque for immediate loading; in some cases, composite torque was 100 Ncm or less. Reported here are the findings and outcomes after 1 year of loading, which included an immediate-function provisional followed by the definitive prosthesis, in 10 maxillary M-4 cases in which at least one implant was unstable, defined as 10 to 15 Ncm of insertion torque.

**MATERIALS AND METHODS**

Ten patients were treated with maxillary All-on-Four immediate-function implant prosthetic treatment following the extraction of residual teeth and creation of a bone shelf by alveolar reduction osteoplasty. All provided informed consent. Patients were selected from a consecutive series of patients treated with All-on-Four and immediate function, and at least one of the loaded implants had an insertion torque of 15 Ncm or less. (The maximum torque permitted was 50 Ncm for any individual implant.) Insertion torque was measured using a standard hand-held insertion device.

All implants were placed in the M-4 pattern with apical fixation at the lateral piriform rim above the nasal fossa (Fig 1a). A fixed provisional was then placed without cantilevers or occlusal deflection (Fig 1b). A soft diet was prescribed for 3 months postsurgery.

The definitive restoration was placed 6 to 9 months later using a one-tooth cantilever (to provide first molar occlusion) supported by a $4 \times 4$-mm square titanium bar (Fig 1c). Panoramic and/or periapical radiographs were obtained on the day of surgery and 6 weeks, 6 months, and 1 year postsurgery. The definitive restoration was supported by a rectangular U-shaped titanium bar with an extension beyond the distal implant of approximately 10 mm for the cantilevered first molar (Fig 2).

**RESULTS**

Ten patients each received four maxillary implants for immediate function (Table 1). All prostheses were stable, with an average A/P spread of 15.6 mm (Table 1).

Implants ranged from 10 to 18 mm in length, with an average length of 13.6 mm. All implants were placed at 30-degree angles and received 30-degree abutments. Average insertion torque per implant was 24 Ncm, while the average composite insertion torque was 98.8 Ncm (range, 80 to 160 Ncm). Half of the patients had composite insertion torque of 100 Ncm or below. No implant lost significant bone or had soft tissue problems. Altogether, 40 implants were placed, all of which osseointegrated and remained in function after 1 year. All provisional and definitive restorations remained stable throughout the study period.

Illustrated in the following is one study patient with a composite insertion torque of 80 Ncm, with the two posterior implants reaching only 10 Ncm.
A 60-year-old patient presented with multiple missing teeth in the maxilla for implant treatment (Figs 3a to 3c). The M-4/All-on-Four treatment scheme was determined to be the most reliable and least invasive of the options discussed, as no bone grafting was anticipated. First, the five remaining maxillary teeth were treatment planned for extraction prior to All-on-Four therapy. The alveolar position in relation to lip dynamics indicates a need for bone reduction to establish adequate esthetics and provide room for the prosthesis.

Table 1  Implant Data for the Treated Patients

<table>
<thead>
<tr>
<th>Pt no.</th>
<th>Implant length (mm)*</th>
<th>Insertion torque (Ncm)*</th>
<th>A/P spread (mm)</th>
<th>Restored?</th>
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</table>

*Shown in the order of teeth 15, 12, 22, 25 (FDI tooth numbers).
the maxillary teeth were extracted and the alveolar bone was leveled. Following removal of cortical crestal bone, type 4 trabecular bone was present, with minimal mineral content. An M-4 distribution was obtained nonetheless by using cortical anchorage apically at M-point bilaterally (Figs 3d and 3e). Insertion torque for each of the anterior implants was 30 Ncm, but only 10 Ncm was achieved for each of the two posterior implants, both of which could be hand-turned and moved slightly side to side after placement. However, all four implants were vertically stable and therefore not compressible. The composite insertion torque of the four implants was therefore 80 Ncm. Following placement of 30-degree angled abutments, an impression was made, leading to placement of the provisional on the same day as surgery (Figs 3f and 3g). The occlusion was adjusted and balanced to avoid deflective contacts, and the patient was placed on a soft diet. The definitive restoration was inserted 8 months later using a 1-cm titanium bar–supported cantilever (Figs 3h to 3j).
DISCUSSION

One of the most common biomechanical theories expressed by dental scientists and clinicians is that implant primary fixation is required for osseointegration to develop.9–12 However, for osseointegration to occur, it is not important that implant healing be quiescent, as local stress and strain augment the bone healing response.13,14 This was recently shown to be mediated through osteoblast primary cilia, which act as mechanoreceptors.15 For intramembranous bone formation, microstrains in the 1,500 to 3,500 range are much more favorable than an unloaded state.16 However, if there are large strains, mechanotransduction does not occur, as osteoblasts turn away from the principal strain axis and fibrous encapsulation ensues.16 Therefore, excessive movement between a titanium element and the osseous interface can cause high interfacial strain that will prevent osseointegration.

In the case series reported here, some of the implants could be hand-turned or toggled side to side because of poor bone quality. At times, one- or two-wall defects were present, but adequate fixation was still obtained secondarily from the prosthetic device. Nevertheless, one clinical variable was required for compromised implants to osseointegrate, ie, vertical stability; in other words, the implant could not be compressible. As long as each implant had a vertical stop and could be splinted statically to prevent horizontal displacement, osseointegration occurred. This finding, if verified in a larger patient sample, should have great clinical significance by allowing a greater proportion of eligible patients to proceed to immediate function with All-on-Four therapy.

Another consideration for immediate function is bone-to-implant contact. Animal experiments in cortical bone have indicated that the initial mechanical bone/implant junction does not degrade as a result of immediate function17; in fact, there is no loss of bone/implant contact during immediate function in cortical bone. Apparently, as long as the implant remains fixed in place there is no adverse effect on the bone/implant interface, even during the demineralization phase or early bone modeling prior to osseointegration. In the cases reported here, however, there was minimal cortical bone, with almost no direct bone contact with the newly placed implants. In fact, there was generally only apical fixation of a few millimeters, an alveolar pass-through of poorly mineralized trabeculae, and an absence of alveolar crestal cortex as a result of bone reduction.18 But even in this setting, when there was minimal or even no contact, osseointegration developed, as long as the prosthesis was not compressible.

Displacement of dental implants in trabecular bone or where there is minimal cortical anchorage and therefore low insertion torque is affected by both the magnitude of the force and the angle of the load with respect to the vertical axis.19 In one study that used fresh bovine bone specimens in type 4 bone, short and long implants were compared with various static lateral force magnitudes. The study found that greater lateral forces induced greater implant displacement.19 However, longer implants had significantly less displacement. For example, a 30-N lateral force on a 15-mm-long implant displaced the implant 51 μm, whereas for a short implant (8.5 mm) the displacement was 396 μm. For the study, critical displacement was considered 100 μm, which was not reached at this level of static force for the longer implants.19

Angled implants are almost always longer than axially placed implants. Thus, with angled implant placement in poorly mineralized bone, length may have a contributory effect for resistance form, even though loading is cyclical in nature (Fig 4a). In the maxilla, implant length is enhanced by approximately 50% with the M-4 placement pattern, where both the nasal fossa and sinus are avoided by implant angulation.3 This approach increases length significantly, often resulting in very long implants—up to 15 to 18 mm—to obtain fixation.

Somewhat analogous to angled implant placement is cantilever loading, a relatively nonaxial type of loading, in which the midportion of the implant within the trabeculae undergoes greater bone strain in comparison to axially placed implants.20 Furthermore, there is an increase in dynamic remodeling of the trabecular bone in nonaxial (cantilever) loading.20 Similarly, angled implants have increased load transmission within the trabeculae and a greater remodeling response within the marrow than with vertical placement. For immediate function, then, this indicates that the walls of the implant may play an important role in the initial load-bearing capacity, as well as the establishment of osseointegration later on (Fig 4b).

The complex conformation of four implants placed at disparate angles may provide internal secondary stabilization, even with very little bone contact. Four implants placed in an M-shaped pattern creates implants that diverge at 60-degree angles from each other within the bone (Figs 4c and 4d).2 Although the provisional prosthesis helps to prevent shear forces, it cannot in itself prevent lateral load displacement.21–23 The M-4 pattern “braces” the restoration, much like diagonal (truss-type) bracing reinforces weight-bearing panels in structural engineering.24 Although this bracing action can be overcome by lateral loads, such as those exerted during bruxism,25–28 clinicians must remain aware that the traditional concept of implant overload, such as progressive bone loss or self-limiting angular bone loss.
that stabilizes, is not the same type of overload found with immediate function in bone-compromised implants. Bone strain is manifested most at the apical threads, where anchorage is under the greatest stress and the trabeculae are probably withstanding physiologic tensile bone strains in the range of 1,000 to 3,500 microstrains. But when bone failure occurs apically, it can be sudden and "catastrophic," leading to the loss of all four implants, since the load-bearing capacity of the trabecula is limited.

Compressive load resistance is also associated with the M-4 pattern of implant placement; once again, the load engages the walls of the implant along its length. Remarkably, load bearing does not require that all four implants have primary fixation in bone. As long as at least two secure supporting elements are present in the splinted construction, compressive loads will not displace the prosthesis.

The greater the vertical bone deficiency, the greater will be the stress/strain for an osseointegrated implant.
in bone, as evidenced by finite element analysis.\(^{29}\) In this setting, in which long implants are used that may have very limited bone contact apart from apical fixation, this suggests a relative magnification of stress in the basal cortical bone anchorage. This precarious immediate function load-bearing strategy requires load sharing by adjacent well secured implants to prevent biomechanical failure. After the immediately loaded implants become osseointegrated along their full length, apical stresses will dissipate crestally as load-related remodeling reaches equilibrium.\(^{31,32}\)

The prosthesis itself acts as a shear panel, essentially holding implants in position, and vice versa.\(^{33}\) This would include the use of conical abutments, which have been shown to reduce interfacial shear stress in the bone.\(^{33}\) Typically, cantilever action is absent posteriorly, although it is present anterolaterally. The anterior cantilever then requires well fixed implants anteriorly, making the anterior implants the most important elements for All-on-Four immediate function (Fig 4f).

When two of the four implants are unstable, the stable implants must be the anterior two implants, or implants at diagonals from each other, to proceed with immediate loading. Unfavorable settings for loading would be two adjacent implants on the same side or two unstable anterior implants. In cases of opposing natural dentition (or bruxism), all four implants must be stable; it is recommended that the A/P spread be extended from 15 to 20 mm and a composite insertion torque of 120 Ncm or greater should be retained.

In any case, the prosthesis acts as a stress shield to the implants, in contrast to individual unsplinted implants (Fig 4g).\(^{23,33}\) This process could be termed external secondary stabilization. The mathematics of this finding have been established by the Skalak-Brunski model (Figs 5a and 5b), which demonstrates that implant forces in a four-implant distribution are similar to those of a six-implant case, depending on the A/P spread.\(^{34}\)

**CONCLUSIONS**

Ten patients were treated with maxillary All-on-Four immediate function using 30-degree angled implants in which one or more individual implants had an insertion torque of 15 Ncm or less. The suggested composite insertion torque threshold of 120 Ncm was not reached in half of the patients. Nevertheless, all low-insertion-torque implants survived over the 1-year study period in this consecutive patient series. These preliminary findings indicate that immediate function may possibly be expanded to more candidates, although the findings must be verified by multicenter long-term studies with statistical power.
In 1983 the Skalak mathematic model established that a given number (n) and arrangement of implants with a defined A/P spread will follow a biomechanical equation, as shown here, for which horizontal and vertical loading by force P can be calculated. Reprinted from Brunski34; used with permission.

Results from the Skalak-Brunski model for a four-implant scheme versus a six-implant scheme with arcs of 112.5 degrees showing that the forces on the implants are not dramatically different. Reprinted from Brunski34; used with permission.

\[ F_i = \frac{P}{N} n_i + \frac{P e}{SR_i^2} n_i \]

\[ F_i = \frac{P}{N} + P(Ax_i + By_i) \]

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**REFERENCES**


