

# A Custom Template and Definitive Prosthesis Allowing Immediate Implant Loading in the Maxilla: A Clinical Report

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**Purpose:** The purpose of the present investigation was to examine to what extent precision data from 3-dimensional planning software for oral implants can be transferred to the operative field by means of a drilling template, containing high-precision drilling sleeves, fitted on the jawbone. It was investigated whether this procedure would allow advance preparation of a fixed definitive prosthesis that could be placed at the completion of surgery. **Materials and Methods:** This procedure was experimentally carried out in 2 cadavers and later in 8 consecutive human patients. **Results:** The results indicated a nearly perfect match between the positions and axes of the placed implants and those planned. **Discussion:** This procedure permitted the placement of a definitive fixed prosthesis with limited freedom of space between the abutments and the metallic cylinders incorporated into the prosthesis. **Conclusion:** These encouraging results of the Leuven information technology-based oral rehabilitation by means of implants (LITORIM) are presently being further investigated at the clinical level. (INT J ORAL MAXILLOFAC IMPLANTS 2002;17:663-670)

**Key words:** computed tomography, computer-aided design, computer-assisted machining, dental implants, virtual reality

Although it appears that 2-stage surgery, as proposed by Brånemark and colleagues in the mid-1960s,<sup>1</sup> remains the most reliable procedure for achieving the osseointegration of oral implants,<sup>2</sup>

several reports have indicated that a 1-stage procedure with delayed, early, or immediate loading can provide satisfactory results.<sup>3</sup> Since only 1 surgery is needed, the time of edentulism can be reduced from months to less than 1 day.

The semantics used are often confusing, with mixing of such terms as *immediate*, *early*, or *delayed* loading. *One-stage surgery* evidently means that the implant (and abutment) immediately protrude through the soft tissues, but *immediate loading* should indicate the provision of occlusal contact within a few days of implant placement. *Early loading* refers to occlusal contacts imposed after 1 or 2 weeks.<sup>4</sup> The term *delayed loading* seems appropriate when a delay of several weeks (often 4 to 6)<sup>5</sup> occurs before placing the dental prosthesis, which will transfer the occlusal load to the oral implant. These time lags are arbitrary but should help clarify what is meant. Whether they correspond to different histologic and biomechanical situations remains unknown. However, animal experiments have demonstrated a distinction between loading before and after 1 week following implant placement.<sup>6</sup>

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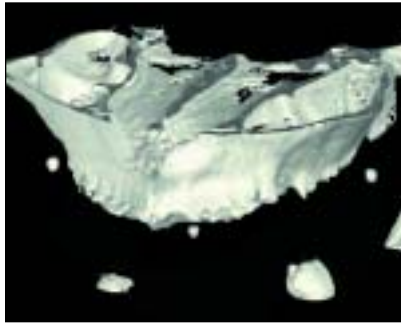
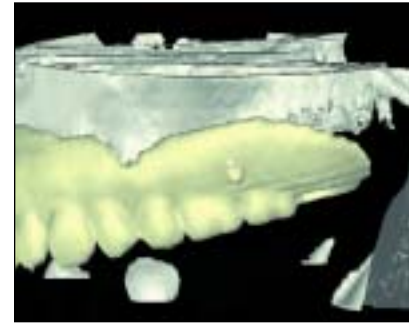
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**Figs 1a to 1c** Fusion of the bone and prosthesis CT scan images.**Fig 1a** With a normal kilovoltage (kV), only the jawbone and the markers glued to the patient's prosthesis are visible.**Fig 1b** With a low-kV image of the prosthesis alone, the latter becomes visible; the markers are also still visible.**Fig 1c** The 2 previous images are fused by a matching of the reference points (markers).

When 1-stage surgery is applied, there is already loading of the endosseous implants, from the surgical phase onward, through the food bolus or through an occlusal contact if this is attainable by the patient. This likely involves much lower forces than when a full occlusal load is present. These accelerated loading schemes have often involved the use of roughened implant surfaces, which are known to favor accelerated bone apposition,<sup>7</sup> although the machined surface can also allow early<sup>8</sup> and even immediate loading,<sup>3</sup> at least in the symphyseal area.

The presence of ample bone volume with a fair degree of mineralization, as encountered in the symphyseal area, evidently can permit such early<sup>9,10</sup> or even immediate loading.<sup>3</sup> For the Brånemark Novum System (Nobel Biocare, Göteborg, Sweden), wherein a standard prefabricated bar is used to carry the fixed prosthesis the same day, short-term survival rates for individual implants (3 per patient, rigidly interconnected) have been reported to be in the order of 98% after 1 year. This immediate loading suggests a good result, but the long-term outcome should still be compared with the 99% cumulative survival rate for individual implants after 15 years<sup>2</sup> obtained with the same implant type when a 2-stage procedure is used. A 1-stage procedure in the same area using machined implant surfaces with delayed loading (within 3 weeks) has revealed success rates no lower than a 2-stage approach.<sup>11</sup> The symphyseal area appears to be advantageous for best results for all implant configurations when a 2-stage procedure is used.<sup>12</sup>

Encouraged by reports indicating that early and even immediate loading can result in osseointegration, a new approach has been developed, based on a high-precision 3-dimensional (3-D) computed tomographic (CT) image implant planning system,<sup>13-15</sup> which is applicable in both jaws. It is called LITORIM (Leuven information technol-

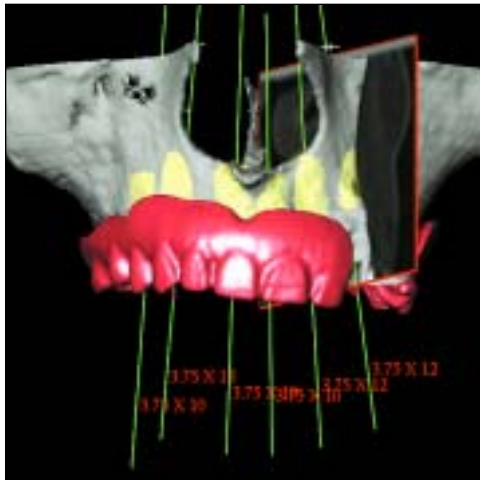
ogy-based oral rehabilitation by means of implants). It consists of a custom-fit template adaptable to the jawbone surface which, by the inclusion of removable sleeves with diameters precisely adapted to the series of drills and the implants themselves, offers precision in transferring the planned orientation for drilling to the surgical field. This facilitates placement of the prosthesis at the end of surgery. Both the template and the prosthesis are fabricated on the basis of a combination of 3-D software planning and clinical data.

The present article reports the results obtained in the edentulous maxilla of 2 *ex vivo* specimens and of 8 consecutive patients.

## MATERIALS AND METHODS

### Three-dimensional Planning Software

Data acquired through a spiral CT of the maxilla, while the patient is wearing a denture or specially created waxup, are coordinated by 3-D oral implant planning software.<sup>13-15</sup> Only a brief outline will be noted here. Concerning image acquisition, small radiopaque markers (gutta-percha balls) are glued to the approved prosthesis, or on a specially created waxup if the former is not optimal. This prosthesis is placed in the CT scanning device a second time for scanning with low energy to make it visible. The 3-D planning software then fuses the 2 images—that of the patient wearing the prosthesis, and that of the visible prosthesis only. This is accomplished on the basis of the radiopaque markers, which are easy to discriminate in both images. The software program allows, by a click of the mouse at any time, the viewing of images with or without the denture visible or with or without the bone visible (Figs 1a to 1c). It is designed to be in open GL mode as fully 3-D, in contrast to currently marketed systems, which are 2-D or 2.5-D.



**Fig 2** The 3-D planning by simultaneous views in several planes takes into account the associated bone characteristics and the planned prosthesis.



**Fig 3** The model prepared on the basis of the 3-D program includes replicas of the planned implants and the gingival contours.

It is best compared to a series of cameras that give views of the same object at different angles at the same time. A split-screen thus permits visualization and manipulation in real time of the different reformatted planes or the global view (Fig 2). Whatever is done in one view automatically appears at the same time in all other views. Because of the spiral CT scan protocol used, the precision obtained is noteworthy with respect to anatomic reality. With introduction of the planned prosthesis, the planning is driven both by the bone quality (location of cortical layer) and quantity and the planned prosthesis to optimize esthetics, phonetics, and maintenance.

### Premanufactured Drilling Template and Definitive Prosthesis

An epoxy resin model is fabricated on the basis of the CT scan data. To manufacture a stereolithographic model, a solid or a surface model made in 3-D computer-aided design is needed. The 3-D data are then converted into a \*.stl file. The \*.stl file is an approximated 3-D model made up of triangles. The difference between the sides of the triangles and the nominal model surface can be adjusted with parameters, ie, cord height/maximum facet deviation, that are usually between 0.02 and 0.10 mm. Smaller cord height gives smoother parts.

Orientation of the file and slicing in the z-axis direction with 0.10- to 0.15-mm layer thicknesses is then made. The result is a large amount of polygons with 1-layer thickness “stapled” to each other in a

process file. This file can then be rendered by the stereolithographic machine. The stereolithographic machine moves an ultraviolet laser according to the information in the process file and makes a selective hardening of a liquid epoxy resin formed in layers. Typical accuracy is 0.1 to 0.2 mm. After the building process, the model is washed clean of any unhardened resin, after-treated in an ultraviolet oven, and then finished with polishing, painting, etc.

This model reproduces, with precision, the jawbone and dental prosthesis with a space in between representing the gingiva and mucosa. The prosthesis is connected to the jaw model through small spikes, which are automatically manufactured. The implants, as planned in the virtual images, are now placed as replicas into the predetermined holes in the model, and the gingiva is mimicked (Fig 3).

This series of metallic cylinders can harbor removable titanium sleeves of different diameters, which will direct the drills, taps, and implant holders. The drilling template has high rigidity because of the carbon fiber-reinforced technology.

An acrylic resin tooth setup in wax of the prosthesis, with patient-approved shapes and shades, is used to fabricate the definitive prosthesis based on the same carbon fiber-reinforced technology. The prosthesis contains metallic cylinders with an inner diameter slightly (0.3 mm) superior to titanium abutment cores, which will be screwed later onto the placed implants. The latter are cemented within the cylinders of the definitive prosthesis.



**Fig 4** The drilling template, which fits intimately onto the jawbone and is fixed by 2 expanding abutments, harbors a drilling sleeve, which guides the drill along the planned axis, whatever the tilting forces may be.



**Fig 5** Lateral fenestrations in the template assist the surgeon in maintaining visual control and facilitating the removal of bone chips.



**Fig 6** In this patient with a narrow ridge, 8 implants of 3.75 mm diameter were placed uneventfully without any fenestrations or dehiscences.

### Surgery

Surgery is performed under local-regional anesthesia, with appropriate asepsis and sterility.<sup>16</sup> Oral sedation is often used, as is atropine to reduce salivary flow and the opportunities for operative field contamination. Prior to the surgery, the patients rinse for 1 minute with chlorhexidine digluconate solution 0.2% (Corsodyl, SmithKline Beecham, Genval, Belgium).

In the maxillary situation, a midcrestal incision is made to uncover the maxilla from its mucoperiosteum over some 1 cm on both sides of the crest. This allows sufficient seating of the drilling template, which fits intimately on the bone surface. In completely edentulous maxillae, the curvature of the drilling template reduces the degrees of freedom to zero, allowing the surgeon to fit the template without hesitation to the underlying jawbone. The metallic cylinders, which are inserted in the template, contain a series of titanium sleeves with different diameters that exactly match the series of twist drills (Fig 4), taps, and implant mounts used in the Brånemark System. Thus the drilling is guided and even forced with precision along the planned axis. One site somewhat in the middle of each side of the jaw is chosen for initial drilling. At this stage, the drilling template must still be maintained by hand. After the first 2 implants (Mark III, Nobel Biocare) are placed at those 2 sites, a specially designed expanding abutment mount is placed on top of them to rigidly fix the template in the position obtained. Subsequently, the other sites are all prepared in series freehand. The height of the template had been calculated in such a way that the drill guides and implant mounts can always be used until the holder touches the top of the sleeve. This means that the surgeon does not have to pay attention to the depth of drilling; however, the fenestrations present in the template allow visualization at any time (Fig 5).

When all implants have been placed, both the expanding implant mounts and the drilling template are removed, revealing the series of placed implants (Fig 6).

In this example, between 6 and 10 implants were placed in the maxilla with lengths of 8.5 to 15 mm and diameters of 3.75 or 4.0 mm. In the 1 patient treated in the mandible, 5 implants were placed with a minimal 10-mm length. The group consisted of 6 men and 2 women ages 54 to 64 years.

### Prosthesis Placement

The prosthodontist loads the planned abutments with the accompanying guide pins with slow-curing resin cement. The abutments are subsequently introduced one by one in the cylinders of the definitive prosthesis corresponding to the planned axes in the 3-D planning system (Fig 7). Then by means of the guide pins, the abutments are screw-tightened onto the placed implants before the cement sets (Fig 8). Once the setting is fully achieved, the manual pressure maintained to avoid any movement is released and any excess cement is carefully removed. At this stage, the surgeon closes the gingiva under the prosthesis with self-resorbing sutures.

The occlusion and articulation are carefully checked and adjusted where needed. Simultaneous contact in centric relation as well as canine and anterior tooth rise in excursions was designed. Eventually, all screw access holes are temporarily sealed. All prostheses had 1 or 2 teeth distal in extension.

### Postoperative Care

A postoperative orthopantomogram is used to verify abutment seating on the implants (Fig 9).

Patients receive 500 mg of paracetamol at the end of surgery and are instructed to use this analgesic, only because it does not inhibit prostaglandin



**Fig 7** (Left) The prosthesis, prefabricated on the basis of the CT scan and clinical data, is made of fiber-reinforced carbon and contains a number of metallic cylinders. Three abutments loaded with the autopolymerizing resin are visible.

**Fig 8** (Right) The prosthesis with abutments, which are screwed into place by means of guide pins, is cemented to the abutments with a slow-curing resin.

**Fig 9** Radiographic view showing the abutments and implants carrying the carbon fiber-reinforced prosthesis with distal extensions.



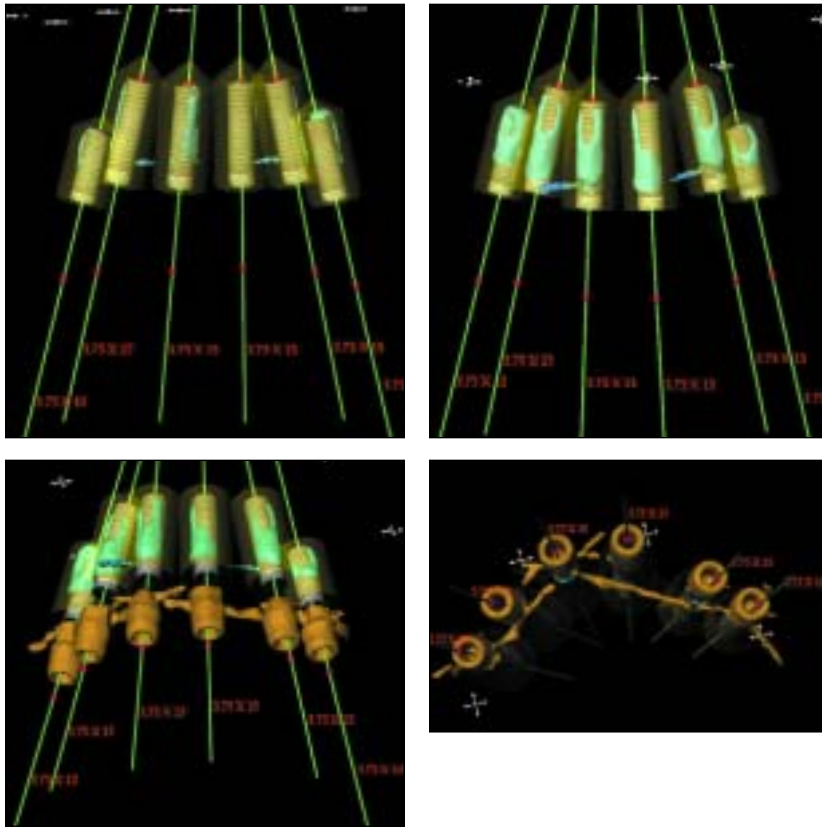
synthesis, 4 to 6 times a day for as long as necessary. Patients are also instructed to use a chlorhexidine rinse twice a day for the next 4 weeks and to eat only food with soft consistency (fish, ground meat, etc) for the next 2 months. The resorbable sutures are removed if necessary after 10 days and wound hygiene is performed at that time if necessary. The prosthesis is left in place, to be removed after 1 year, and then only to examine the stability of individual implants.

## RESULTS

The trial in the 2 cadaver specimens indicated that the drilling template achieved the appropriate fit to the underlying bone. The drills and especially the slow turning taps and implants were well guided because of their intimate fit with the inserted sleeves. The whole procedure—always less than 90 minutes even when as many as 10 implants were placed—was expedited by the fact that all drilling could be done at full length in the predetermined sleeve cylinders. After surgery, a new CT scan was taken, and the planned and achieved implant locations and axes

were compared based on an image volume registration technique also applied by Van Cleynenbreugel and associates.<sup>17</sup> At the level of implant entry in the maxilla, the match was on average within 0.8 mm (SD 0.3), and at the target level the match was on average within 0.9 mm (SD 0.3). The differences in distance between planned and achieved entry and target locations were most prominent in the longitudinal direction of the implants (maximum 1.1 mm). Finally, the match between planned and actual implant axis was on average within 1.8 degrees (SD 1.0) (Figs 10a and 10b).

During surgery, several patients demonstrated a narrow ridge in some locations, so the use of the removable sleeves appeared crucial. When tapping at slow speed or when implant placement is performed with a free hand, the surgeon often experiences difficulties in avoiding deviation from the predrilled track. Even with unequal crestal bone levels or differences in bone density, the present sleeve system forces the tap or implant in the proper direction. There is eventually a feeling of wobbling, but the tap or implant is forced into the right direction. Thus, even narrow ridges could accommodate standard-diameter implants with no difficulty.



**Fig 10a** To demonstrate the precision of the 3-D planning to clinical reality in 2 cadavers, the postoperative CT was superimposed on the preoperative planning. First, the 2 different colors attributed to the respective data illustrate the concordance of implant positions and axes.

**Fig 10b** The fit between the axes of the implants and the prefabricated prosthesis, (only its titanium cylinders are visible) is striking.

In the 8 consecutive patients, all implants were used successfully for connecting the abutments. One implant could not be used, since its position had deviated from what was originally planned because of a sleeve forgotten at the stage of implant placement. The fit between the abutments and the implants was verified by postoperative orthopantomograms. A slight space appeared on 5 of the 61 placed implants as the result of difficulties in keeping visual control during the screwing of the abutments onto the implants. This did not occur in any of the last 5 patients, where slightly more narrow abutments were used.

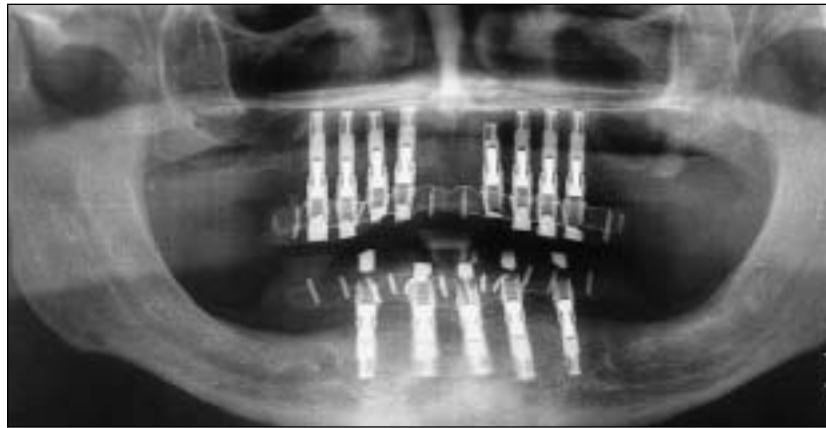
All 8 patients, with 12 months follow-up thus far, demonstrated a stable and well functioning prosthesis (Fig 11). They resumed normal food intake after approximately 2 months. Their satisfaction with chewing and phonetic comfort, in addition to esthetics, remained high for all as ascertained by questioning. The Gingival Index remained low, but

probing pocket depth could not be properly assessed in instances where an overhanging prosthetic restoration was present.

## DISCUSSION

It appears from the present short-term results that it is possible to achieve proper support for a cross-arch full fixed prosthesis supported by multiple implants in the maxilla and placed at the time of implant placement. This can be facilitated by means of a precise 3-D planning system based on drilling templates and rigid prostheses, a new concept known as LITORIM. Thus far it has been impossible to assess how well the implants have achieved osseointegration, since this would require removal of the cemented prosthesis to check for immobility of the unconnected implants.<sup>12</sup> The present study has revealed that an implant plan based on a preoperative

**Fig 11** In this patient a LITORIM approach was used in both the maxilla and mandible.



CT scan can be transferred successfully to the operative field and facilitate the preoperative fabrication of a definitive prosthesis. This transfer methodology can shorten the surgical time significantly, even if these first patients are within a learning curve.

What has now been achieved in the maxilla, where bone quality and quantity may be less than optimal, may be extrapolated for application in the edentulous mandible. This treatment approach offers the advantage of providing optimal esthetics and phonetics utilizing a custom-fit approach. However, in contrast to the Brånemark Novum System, where both surgical and prosthetic hardware are standardized and prefabricated, the LITORIM approach uses custom-fit prefabricated hardware. The technology is not in a stage that makes a proper comparison between the two systems possible.

The present and other data do not render the 2-stage approach obsolete. Indeed, the 2-stage approach will be difficult to match considering the documented 15 years of 99% cumulative success rates obtained with a screw-type machined implant configuration.<sup>2</sup> However, the treatment option under consideration could be used for patients in whom the number of surgeries should be limited because of general health problems, or for those who need an expedited oral rehabilitation for personal reasons.

Whether used for 1- or 2-stage surgery, the use of drilling templates with precision sleeves will allow the treatment of patients with narrow ridges which would otherwise be surgically challenging if not impossible.

## SUMMARY

When proper diagnosis and treatment planning indicate the need to deviate from the highly predictable 2-stage approach to achieve osseointegration, the present controlled surgical prosthetic approach offers a global concept for immediate loading using a definitive fixed prosthesis.

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