Chapter 1

Introduction
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The resorption pattern of the alveolar process that takes place after tooth extraction has been the object of many classifications of the edentulous jaws. Wical et al.\textsuperscript{[1]} presented a classification for the edentulous mandible based on 130 orthopantographic radiographs. Findings revealed that the distance between the basal border of the mandible and the alveolar foramina corresponded to a constant third of the mandible’s height when dentate. Based on this quantitative measuring, the authors concluded that the architecture of the two coronal thirds markedly changed while the apical third remained stable. Lekholm et al.\textsuperscript{[2]} classified edentulous jaws into five degrees of alveolar ridge resorption, based on lateral cephalometric radiographs. This study considered both form and bone quality of the edentulous jaws. Cawood et al.\textsuperscript{[3]} investigated morphological jaw changes of 300 dried skulls, and similarly to Wical et al., found the basal bone unchanged.

Other proposed specific classifications of edentulous jaws based on implant placement possibilities considered radiographic and clinical parameters, as well as the degree of bone remodelling.\textsuperscript{[4]} These classifications mainly described implant sites by bone quantity and quality, and by proximity to vital structures.

A variety of prosthodontic classifications and treatment proposals for restoring edentulous jaws with either removable or fixed implant-supported rehabilitations have been presented in dental literature.\textsuperscript{[2],5,6,7,8,9,10,11,12,13,14}\textsuperscript{[3]} Observational data collected from panoramic radiographs of 168 complete edentulous patients who received prosthodontic treatment from 1989 to 2005 allowed for a categorization based on the possibility of virtual placing of at least 8mm implants along the edentulous arch without interfering with anatomic structures (maxillary sinuses, nasal cavity, and mandibular alveolar nerves). Based on these observations, 4 different categories (C1-C4) reflecting increasing degrees of alveolar ridge resorption can be distinguished.

**Category 1 (C1)**

Maxilla C1, defined as edentulous maxillae where alveolar bone height permitted virtual placing (measured with a millimetered implant rule) of at least 8mm implants in the anterior
and bilaterally in the posterior sectors, without interfering with maxillary sinuses and nasal cavity. (Fig 1a)
Mandible C1, defined as edentulous mandibles where alveolar bone height permitted virtual placing of at least 8mm implants in the anterior and bilaterally in the posterior sectors, without interfering with the alveolar nerve. (Fig 1a)

**Category 2 (C2)**
Maxilla C2, defined as edentulous maxillae where alveolar bone height permitted virtual placing of at least 8mm implants in the anterior and one posterior sector. (Fig. 1b)
Mandible C2, defined as edentulous mandibles where alveolar bone height permitted virtual placing of at least 8mm implants in the interforaminal region and one posterior sector. (Fig. 1b)

**Category 3 (C3)**
Maxilla C3, defined as edentulous maxillae where alveolar bone height permitted virtual placing of at least 8mm implants only in the anterior maxilla. (Fig. 1c)
Mandible C3, defined as edentulous mandibles where alveolar bone height permitted virtual placing of implants of at least 8mm only in the interforaminal mandibular region. (Fig. 1c)

**Category 4 (C4)**
Maxilla C4, defined as edentulous maxillae where virtual placing of at least 8mm implants interfered with both maxillary sinuses and nasal cavity. (Fig. 1d)
Mandible C4, defined as edentulous mandibles where virtual placing of at least 8mm implants interfered with alveolar nerves bilaterally in posterior sectors. In the interforaminal anterior region, the alveolar bone height was of 10 mm or less. (Fig. 1d)
Variances within individual patient categories were also evaluated. “Category–specific” prosthodontic options were proposed, taking into account rationale treatment planning of an implant-supported rehabilitation.

**Figure 1**
Schematic drawing of the four characteristic categories found on orthopanoramic radiographs of completely edentulous patients.
A: Category 1 (C1)
Maxilla: alveolar bone height in the anterior maxilla and bilateral posterior sectors allowing for the placement of at least 8mm implants. Maxillary sinuses and nasal cavity are at distance from the regions of implant placement.
Mandible: alveolar bone height in the anterior maxilla and bilateral posterior sectors allowing for implant placement. Alveolar nerves are at a distance from the regions of implant placement.

B: Category 2 (C2)
Maxilla: alveolar bone height allowing for placement of at least 8mm implants in the anterior maxilla and one posterior sector. Unilaterally, the posterior alveolar bone height does not allow for implant placement.
Mandible: alveolar bone height in the interforaminal region and one posterior sector allowing for implant placement. Unilaterally, the posterior alveolar bone height does not allow for implant placement.

C: Category 3 (C3)
Maxilla: alveolar bone height allowing for placement of at least 8mm implants only in the anterior maxilla. In both posterior regions, alveolar bone height does not allow for implant placement.
Mandible: alveolar bone height is available for implant placement only in the interforaminal region. Bilaterally, bone height does not allow for implant placement.

D: Category 4 (C4)
Maxilla: alveolar bone height is not available for placement of at least 8mm implants along the entire edentulous arch because of significant bone resorption.
Mandible: alveolar bone height is not available for implant placement in the posterior sectors and the interforaminal area is 8mm or less.
The dynamic process through which a human being becomes edentulous plays an important role in determining the final anatomy of the edentulous jaw. This remodelling process that affects external jaw morphology and internal structures is influenced by anatomic, metabolic, prosthetic, and edentulism sequential factors. [15], [16], [17], [18], [19]

The expansion of maxillary sinuses, as well as the alveolar ridge resorption after teeth extraction, often leads to a more severe atrophy of the maxilla. [20],[21],[19]

“Category-specific” Prosthodontics Considerations

Fixed implant rehabilitations for the edentulous jaw can be proposed according to this anatomic radiographic categorization.

Doubtless, C1 (fig. 1a) represents the most favorable situation for implant treatment in both maxilla and mandible (table 1a and b). When the posterior sectors present adequate native bone for implant placement, fixed implant-supported prosthesis can be selected as a treatment option.
For fixed “one-piece” prostheses, ideal implant distribution should guarantee a design free of distal cantilevers in both mandible and maxilla. In a fixed but segmented rehabilitation, a strategic implant distribution will ensure that FPDs are supported by two implant abutments (fig. 2 and 3 a-b).[12],[13],[14] The ideal prosthodontic protocol in C1 patients includes a maxillary implant allocation as Right first Molar (RM1), Right first Premolar (RPM1), Right Canine (RC), Right Central Incisor (RCI), Left Central Incisor (LCI), Left Canine (LC), Left first Premolar (LPM1), Left first Molar (LM1). This implant distribution allows for segmentation of a full arch rehabilitation, in four three-unit FPDs. In the mandible, implants distributed as RM1, RPM1, RC, LC, LPM1, LM1, can allow for segmentation in two three-unit FPDs and one six-unit FPD from canine to canine, including all lower incisors as pontics.

Prosthodontic options for C1 can in most cases be applied to C2 patients (Table 1a and b). For maxillary C2, fixed one-piece implant rehabilitation in C2 patients can still offer a relatively simple solution by restoring the insufficient posterior sector with a distal cantilever. In a fixed but segmented restoration, implant allocation in the posterior sector unable to receive implants will need a minor modification in comparison to C1 prosthodontic design. In the maxilla, this unilateral posterior sector unable to receive implants can be restored with the most distal implant placed at 2nd Premolar (PM2) position instead of at 1st Molar and one single-unit distal cantilever. In the mandible, the location of the emergence of the alveolar nerve will condition implant allocation. If implants can be placed to reach the 2nd Premolar area, a single unit cantilever can be envisioned. Implants shorter than 8mm could be considered as a valuable alternative to rehabilitate mandibular posterior sector with marked bone resorption.[22],[23],[24],[25]

Special consideration should be given to C3 (fig. 1c) that represents the most common group. Here, both posterior sectors are incompatible to host dental implants. This normally leaves the pre-maxilla up to the PM1 region available for implant placement. For one-piece fixed rehabilitation in C3, where implant allocation is confined within the PM1s region, a design with distal cantilevers can be proposed. A tilted implant method in the posterior part of the jaws was suggested to further distally extend fixed implant prostheses.[26] Although this method advises the use of tilted longer implants, implant’s emergence profile should still guarantee an appropriate relationship with prosthodontic superstructures.

A fixed but segmented rehabilitation in a C3 patient should be reserved for patients with a skeletal class I. In this context, an implant distribution as RPM1, RC, RLI, LLI, LC, LPM2 with a
segmented design in 3 metal-ceramic FPDs including 2nd Premolars as distal cantilevers, can be considered as an additional prosthodontic solution (fig. 2b, maxilla). These rehabilitations will result in a shortened dental arch and so esthetic parameters should be carefully revised. However, an implant retained overdenture should be considered for C3 patients with unfavourable inter-arch relationship.

In C4 (fig. 1d) prosthodontic options are limited to overdentures.

Table 1a and b summarise different prosthodontic solutions for each category. Chapters 2, 3 and 4 will address the different treatment sequencing and loading protocols. Successful immediate loading in the maxilla can be achieved with cross-arch stabilization, using “fixed provisionals”, [27],[13],[28],[29] as well as in the mandible. [13],[30],[31],[32],[33],[34] While, traditionally, healing periods of 3 to 6 months were considered critical for predictable osseointegration of dental implants, modified surgical and loading protocols have demonstrated predictable outcomes.

Protocols for treatment of edentulous maxilla and mandible with removable or fixed prostheses present a variety of options regarding numbers of implants, their strategic distribution, transitional prosthesis, and definitive prosthetic design. These clinical considerations are generally granted the highest level of importance and, ideally, should not be adapted to facilitate a specific loading protocol. Loading protocols only represent one additional step along the treatment sequence and its implementation should not alter the desired final implant/prosthetic design.

Multiple parameters have been identified as influential factors in successfully achieving osseointegration with modified loading protocols for completely edentulous arches. These factors include patient health, oral conditions, occlusion and function/parafunction, characteristics of the proposed implant site, implant size and shape, implant material and surface properties, implant distribution along the arch, timing and methodology of implant placement including primary implant stability, loading procedures, and long-term maintenance.

The definitions of terms for loading protocols in edentulous patents adopted for the 4th ITI Consensus Meeting are as follows:
Conventional loading:
Dental implants are allowed for a healing period greater than 2 months after implant placement with no connection to the prostheses.

Early loading:
Dental implants are connected to the prostheses between one week and 2 months subsequent to implant placement.

Immediate loading:
Dental implants are connected to the prostheses within one week subsequent to implant placement.

In addition, there is no longer a need for a separate definition of delayed loading since it will be included under the definition of conventional loading.

In order to accurately present the guidelines for selecting the appropriate loading protocol, consideration for the edentulous maxilla and mandible with removable or fixed prosthetic design will be separately analyzed.

Recommendations for loading protocols in edentulous patients presented here are based on the validation process presented in chapter 4.

Chapter 5, 6, 7, and 8 will address the implant and prosthodontics related clinical outcomes. In this context, selection of a specific prosthetic design for the final rehabilitation should consider implant number and distribution, as well as rehabilitation material and the retention mechanism. Fixed one-piece rehabilitation can be fabricated with a metallic framework with commercial acrylic resin and prosthetic teeth, or a metal ceramic design.

The main advantage of this technique is an ideal prosthetic tooth location and facial tissue support regardless of implant position. Principal disadvantages are difficulties in achieving passive fit, as well as speech disruptions.

Finally, a fixed but segmented full arch rehabilitation calls for a strategic implant placement. This prosthodontic guided implant allocation will allow for fabrication of short span ceramic–fused-to-metal FPDs. This simplified design facilitates laboratory work, improves quality of marginal adaptation, and enhances the final esthetic outcome thanks to its interaction with peri-implant soft tissue.[35]

TABLE 1a: Prosthodontic considerations for the treatment planning according to each category.
<table>
<thead>
<tr>
<th>Categories</th>
<th>Prosthodontics aspects</th>
<th>One-piece</th>
<th>Segmented</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maxilla C1</strong></td>
<td><strong>Skeletal class</strong></td>
<td>Any</td>
<td>Class I or II</td>
</tr>
<tr>
<td></td>
<td><strong>N° of Implants</strong></td>
<td>4 to 6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td><strong>Distribution</strong></td>
<td>Along the edentulous arch to reach 1st M region without distal cantilevers</td>
<td>Bilaterally at RM1, RPM1, RC, RCI, LCI, LC, LPM1, LM1</td>
</tr>
<tr>
<td></td>
<td><strong>Immediate loading</strong></td>
<td>Indicated</td>
<td>Indicated</td>
</tr>
<tr>
<td></td>
<td><strong>Final rehabilitation</strong></td>
<td>Full-arch, metal-resin or metal-ceramic.</td>
<td>Segmented in 4 metal-ceramic FPDs.</td>
</tr>
<tr>
<td></td>
<td><strong>Difficulty</strong></td>
<td>Passive fit, speech disruption, esthetics</td>
<td>Cost</td>
</tr>
<tr>
<td><strong>Mandible C1</strong></td>
<td><strong>Skeletal class</strong></td>
<td>Any</td>
<td>Class I or II</td>
</tr>
<tr>
<td></td>
<td><strong>N° of Implants</strong></td>
<td>4 to 6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td><strong>Distribution</strong></td>
<td>Along the edentulous arch to reach 1st M region without distal cantilevers</td>
<td>Bilaterally at RM1, RPM1, RC, LCI, LPM1, LM1</td>
</tr>
<tr>
<td></td>
<td><strong>Immediate loading</strong></td>
<td>Indicated</td>
<td>Indicated</td>
</tr>
<tr>
<td></td>
<td><strong>Final rehabilitation</strong></td>
<td>Full-arch, metal-resin or metal-ceramic.</td>
<td>Segmented in 3 metal-ceramic FPDs.</td>
</tr>
<tr>
<td></td>
<td><strong>Difficulty</strong></td>
<td>Seating, speech disruption</td>
<td>Cost</td>
</tr>
<tr>
<td><strong>Maxilla C2</strong></td>
<td><strong>Skeletal class</strong></td>
<td>Any</td>
<td>Class I or II</td>
</tr>
<tr>
<td></td>
<td><strong>N° of Implants</strong></td>
<td>4 to 6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td><strong>Distribution</strong></td>
<td>Bilaterally to reach Premolar/Molar region.</td>
<td>Bilaterally at RPM2, RPM1, RC, RCI, LCI, LC, LPM1, LM1</td>
</tr>
<tr>
<td></td>
<td><strong>Immediate loading</strong></td>
<td>Indicated</td>
<td>Indicated</td>
</tr>
<tr>
<td></td>
<td><strong>Final rehabilitation</strong></td>
<td>Full-arch, metal-resin or metal-ceramic with one distal cantilever.</td>
<td>Segmented in 4 metal-ceramic FPDs with RM1 as a distal cantilever</td>
</tr>
<tr>
<td></td>
<td><strong>Difficulty</strong></td>
<td>Seating, speech disruption, esthetics</td>
<td>Cost</td>
</tr>
<tr>
<td><strong>Mandible C2</strong></td>
<td><strong>Skeletal class</strong></td>
<td>Any</td>
<td>Class I or II</td>
</tr>
<tr>
<td></td>
<td><strong>N° of Implants</strong></td>
<td>4 to 6</td>
<td>6</td>
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<tr>
<td></td>
<td><strong>Distribution</strong></td>
<td>To reach Premolar/molar regions</td>
<td>Bilaterally at RPM2, RPM1, RC, LCI, LPM1, LM1</td>
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<td></td>
<td><strong>Immediate loading</strong></td>
<td>Indicated</td>
<td>Indicated</td>
</tr>
<tr>
<td></td>
<td><strong>Final rehabilitation</strong></td>
<td>Full-arch, metal-resin or metal-ceramic (optional distal cantilever)</td>
<td>Segmented in 3 metal-ceramic FPDs (optional distal cantilever)</td>
</tr>
<tr>
<td></td>
<td><strong>Difficulty</strong></td>
<td>Seating, speech disruption</td>
<td>Cost</td>
</tr>
<tr>
<td><strong>Maxilla C3</strong></td>
<td><strong>Skeletal class</strong></td>
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<td>Class I</td>
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<td><strong>N° of Implants</strong></td>
<td>4 to 6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td><strong>Distribution</strong></td>
<td>Bilaterally to reach PM1 areas</td>
<td>Bilaterally at RPM1, RC, RLI, LLI, LC, LPM1.</td>
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<tr>
<td></td>
<td><strong>Immediate loading</strong></td>
<td>Insufficient scientific evidence</td>
<td>Insufficient scientific evidence</td>
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<tr>
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<td><strong>Final rehabilitation</strong></td>
<td>Full-arch, metal-resin or metal-ceramic with bilateral distal cantilevers.</td>
<td>Segmented in 3 metal-ceramic FPDs with PMs2 as distal cantilevers</td>
</tr>
<tr>
<td></td>
<td><strong>Difficulty</strong></td>
<td>Seating, shortened dental arch</td>
<td>Shortened dental arch</td>
</tr>
<tr>
<td><strong>Mandible C3</strong></td>
<td><strong>Skeletal class</strong></td>
<td>Any</td>
<td>Class I</td>
</tr>
<tr>
<td></td>
<td><strong>N° of Implants</strong></td>
<td>4 to 6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td><strong>Distribution</strong></td>
<td>Along the interforaminal area to bilaterally reach PM1</td>
<td>Bilaterally at RPM2, RPM1, RC, LCI, LPM1, LPM2</td>
</tr>
<tr>
<td></td>
<td><strong>Immediate loading</strong></td>
<td>Indicated</td>
<td>Indicated</td>
</tr>
<tr>
<td></td>
<td><strong>Final rehabilitation</strong></td>
<td>Full-arch, metal-resin or metal-ceramic (optional distal cantilevers)</td>
<td>Segmented in 3 metal-ceramic FPDs (optional distal cantilevers)</td>
</tr>
<tr>
<td></td>
<td><strong>Difficulty</strong></td>
<td>Seating, shortened dental arch</td>
<td>Shortened dental arch</td>
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Table 2b: Schematic drawing of “category-specific” prosthodontic options.

<table>
<thead>
<tr>
<th>C1</th>
<th>One-piece</th>
<th>Segmented</th>
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<tbody>
<tr>
<td>C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
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</table>

Distal cantilever Area of Segmentation

Optional cantilever when not opposing fixed implant prosthesis
Chapter 9 will assess the incidence and type of biological and technical complications associated with implant-fixed complete dental prostheses (IFCDPs) for edentulous patients.

References


