Diagnostic value of cone beam computed tomography in complex and compound odontomas: a systematic review and open classification matrix

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Abstract

Objective: Firstly, this review aims to analyse the recent literature about three-dimensional (3D) diagnostic imaging in complex and compound odontomas and compare it to two-dimensional (2D) imaging. Panoramic radiographs help to evaluate the vertical position of odontomas, and occlusal radiographs are used to evaluate the proximity to adjacent teeth. However, cone beam computed tomography (CBCT) can offer volumetric images, and therefore, a more accurate three-dimensional analysis. Secondly, this research aims to construct an open classification matrix for complex and compound odontomas for dentomaxillofacial CBCT radiology protocols based on a systematic literature review.

Material and methods: Two systematic literature searches were conducted in PubMed (Medline), on 2 February 2022 concerning classification systems, and on 5 February 2022 concerning CBCT images.

Results: In total, these searches revealed 391 papers by reviewing the databases mentioned above. Six articles were selected for inclusion on classification of odontomas and 13 articles were found on CBCT imaging. Consequently, the construction of an open classification matrix for compound and complex odontomas for dentomaxillofacial CBCT radiology protocols was performed using these 19 articles.

Conclusions: CBCT offers a more precise position and accurate diagnosis of complex and compound odontomas compared to 2D imaging. Consequently, it enhances the detailed view of the site (multiple or unique), location (intraosseous, partially or completely extra- or intragnathic), size, extension (bony expansion, thinning or perforation cortical bone), density and type (denticulo type, particle type, denticulo-particle type, denticulo-amorphous type, amorphous tissue), relationship (with the crown or root of the definitive tooth), adjacent teeth resorption (deciduous or definitive), adjacent teeth (retention or impaction), and distance with adjacent structures (inferior alveolar nerve, sinus maxillaris), as well as adequate surgical planning. Moreover, this research presents an open classification matrix for the most complete description of compound and complex odontomas when analysing CBCT imaging.

Keywords: cone beam computed tomography, CBCT, complex odontoma, compound odontoma, odontogenic tumour
Introduction

Odontomas are the most common odontogenic tumours, according to the World Health Organization’s (WHO) International Classification of Tumours. Odontomas are defined as malformations or hamartomas in which both epithelial and mesenchymal cells present complete differentiation with enamel formation and dentin [1]. However, all different tooth components can be found in an odontoma (enamel, dentine, cementum, dental follicle, and pulp elements). This odontogenic tumour can occur in two forms: a complex odontoma or a compound odontoma. Mostly these tumours occur at a young age and are usually discovered by coincidence or as tooth eruption is compromised. The diagnosis is therefore usually made around or shortly after tooth eruption, and at that time, calcification of any odontoma is already complete. Odontomas are mostly intraosseous lesions, rarely found in soft tissues, and mostly associated with the permanent dentition. Histologically, the diagnosis is made when enamel and dentine are present [2]. Radiologically, an orthopantomogram (OPG) or panoramic radiographs may help to evaluate the vertical position, level of calcification of odontomas, and impaction of deciduous or permanent teeth, and detailed occlusal radiographs can evaluate their relation to adjacent teeth. However, diagnosis on a two-dimensional image is not always straightforward. Consequently, cone beam computed tomography (CBCT) can reveal a more precise positioning, both vertically and horizontally, the composition of odontomas, root resorption, and closer relations to the adjacent teeth and cortical border [2]. CBCT is used in oral and maxillofacial surgery for its low cost, easy accessibility, and low radiation compared with multi-slice computerized tomography [3]. Therefore, the relevance of CBCT on diagnosis, the value of a classification matrix, and appropriate surgical planning of complex and compound odontomas will be discussed in this review.

Materials and methods

Search strategy

Two systematic search strings on computerized database were conducted on 2 February 2022 (classification) and 5 February 2022 (CBCT figures). The database PubMed (Medline) was used, and a search string was conducted by one observer to identify studies that included two concepts: odontomas and diagnostic imaging. Two search equations were used to build an open classification matrix for compound and complex odontoma for dentomaxillofacial CBCT radiologists. [4-22] Only full free articles accessible were included.

To find already existing classifications on odontoma, the first search equation was used: ("odontoma"[MeSH Terms] OR "odontoma"[All Fields] OR "odontomas"[All
The search was performed on 2 February 2022. The exclusion criteria were articles without CBCT figures of complex and/or compound odontoma, no free access to the pdf of the article, retracted articles, and articles written in other language than English or French. We included only articles with available figures of odontoma using CBCT.

To find CBCT figures of compound or complex odontoma, a second search equation was used: "odontoma"[MeSH Terms] OR "odontoma"[All Fields] OR "odontomas"[All Fields] AND ((ffrft[Filter]) AND (2003:2022[pdat])). The search was performed on 5 February 2022. The exclusion criteria were articles without CBCT figures of complex and/or compound odontoma, no free access to the pdf of the article, retracted articles, and articles written in other language than English or French. Only articles with available figures of odontoma using CBCT were included.

**Article selection**

The time period was limited from 2003 (first CBCT device accessible for dentists) to 2022. The selected languages were English and French. The inclusion criteria were free full text articles on central compound and/or complex odontoma. The exclusion criteria were experimental studies, animal studies, studies not specifically related to compound or complex odontoma. Moreover, available figures on odontoma were searched using CBCT in all selected articles.

**Results**

This search revealed 391 papers by reviewing the databases mentioned above. Consequently, 47 articles were found for the first search string on classification. Six articles were selected [4-9], and 41 articles were excluded. However, these 6 selected articles gave no figures of odontoma when using CBCT.

For the second search string regarding CBCT figures, 344 articles were found. After application of inclusion/exclusion criteria 13 articles were selected. Six articles (and 7 CBCT figures) were found on complex odontomas [10-15]. Seven articles (and 14 CBCT figures) were found on compound odontomas [16-22].

Finally, the construction of the open classification matrix for compound and complex odontoma for dentomaxillofacial CBCT radiologists (Table 1) was performed using 19 articles [4-22]. Both figures from literature as from our patients were included. All figures can be found as ‘FIG’ in this study under the subtitle ‘clinical case presentation’, or as ‘figure’ referring to an open access article with the number of the figure found in the article. Already existing classifications were used,
as well as new classifications. The new classifications from this study are marked as ‘[add]’. The FDI World Dental Federation (ISO) notation was used for teeth numbering.

**Table 1. Open classification matrix for compound and complex odontoma for dentomaxillofacial CBCT radiologists.**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Compound odontoma</th>
<th>Complex odontoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giant odontoma (&gt;3cm)</td>
<td>(figure 3) [14]</td>
<td>(This study FIG 37-Fig 50)</td>
</tr>
<tr>
<td><strong>Quantity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unique site</td>
<td>(figure 2, figure 5) [7]; (figure 3) [16]; (figure 1) [17]; (figure 6A, 6C, 6D) [18]; (figures 3-8) [20]; (figure 1) [21]; (figure 4C) [22]</td>
<td>(figure 1, maxillary tuberosity) [10]; (figures 1, 2) [11]; (figure 1) [12]; (figure 3) [14]; (figure 1) [15]; (figure 6B) [18]</td>
</tr>
<tr>
<td></td>
<td>(This study FIG 1-Fig 25)</td>
<td>(This study FIG 26-Fig 32)</td>
</tr>
<tr>
<td>Multiple sites</td>
<td>(This study FIG 33-Fig 35)</td>
<td>(figure 3) [13]</td>
</tr>
<tr>
<td><strong>Location within the arch</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intraosseous [9]</td>
<td>(figure 3) [16]; (figure 1) [17]; (figure 6A, 6C, 6D) [18]; (figure 2, figure 5) [19]; (figures 3-8) [20]; (figure 1) [21]; (figure 4C) [22]</td>
<td>(figure 1, maxillary tuberosity) [10]; (figures 1, 2) [11]; (figure 1) [12]; (figure 3) [14]; (figure 1) [15]; (figure 6B) [18]</td>
</tr>
<tr>
<td></td>
<td>(This study FIG 1-Fig 19, FIG 21-FIG 25, FIG 33-Fig 36)</td>
<td>(This study FIG 26-Fig 32)</td>
</tr>
<tr>
<td>[add] Pre-erupted state (perforation of alveolar bone on the dental arch)</td>
<td>(This study FIG 20, FIG 33, FIG 34, FIG 36)</td>
<td></td>
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<tr>
<td>----------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>[This study FIG 33, FIG 34, FIG 36]</td>
<td>(This study FIG 1, FIG 3, FIG 4, FIG 15, FIG 16, FIG 18)</td>
<td>(This study FIG 1)</td>
</tr>
<tr>
<td>(This study FIG 26, FIG 27)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Reference</td>
<td>Additional Reference</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Premolar (teeth 15-13, 25-23)</td>
<td>(This study FIG 1-FIG 4)</td>
<td>(This study FIG 26, FIG 42, FIG 45-FIG 48)</td>
</tr>
<tr>
<td></td>
<td>(figure 6D) [18]; (figures 3-8) [20]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(This study FIG 5-FIG 7, FIG 33-FIG 35)</td>
<td></td>
</tr>
<tr>
<td>Molars (teeth 18-16, 28-26)</td>
<td>(This study FIG 33-FIG 35)</td>
<td>(figure 1, maxillary tuberosity) [10]; (figures 1, 2) [11]; (figure 1) [12]</td>
</tr>
<tr>
<td></td>
<td>(figure 2, figure 5) [19]</td>
<td></td>
</tr>
<tr>
<td>[add] Mandible location</td>
<td>(This study FIG 8-FIG 25)</td>
<td>(This study FIG 28, FIG 29)</td>
</tr>
<tr>
<td>Anterior (teeth 43-33)</td>
<td>(figure 3) [14]</td>
<td></td>
</tr>
<tr>
<td>Premolar (teeth 45-43, 35-33)</td>
<td>(This study FIG 42, FIG 43, FIG 45-FIG 48)</td>
<td></td>
</tr>
<tr>
<td>Molar (teeth 48-46, 38-36)</td>
<td>(figure 1) [21]</td>
<td></td>
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<tr>
<td></td>
<td>(This study FIG 5-FIG 7, FIG 11-FIG 14)</td>
<td></td>
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<tr>
<td>Type [4]</td>
<td>(figure 1) [17]; (figure 2, figure 5) [19]; (figure 4C) [22]</td>
<td></td>
</tr>
<tr>
<td>Denticulo-type [4, 6]</td>
<td>(This study FIG 1-FIG 4, FIG 19-FIG 21, FIG 33-FIG 36)</td>
<td></td>
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<tr>
<td>Particle type [4]</td>
<td>(figures 3-8) [20]; (figure 1) [21]</td>
<td></td>
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<tr>
<td></td>
<td>(This study FIG 5-FIG 7, FIG 11-FIG 14)</td>
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<tr>
<td>Denticulo-particle type [4]</td>
<td>(figure 3) [16]</td>
<td></td>
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<tr>
<td></td>
<td>(This study FIG 8-FIG 10)</td>
<td></td>
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<tr>
<td>[add] denticulo-amorphous type</td>
<td>(This study FIG 15, FIG 18, FIG 22-FIG 25)</td>
<td>(This study FIG 42, FIG 43, FIG 45-FIG 48, FIG 50)</td>
</tr>
<tr>
<td>Amorphous tissue [4]</td>
<td>(This study FIG 15, FIG 17, FIG 25)</td>
<td>(figure 1, maxillary tuberosity) [10]; (figures 1, 2) [11]; (figure 1) [12]; (figure 3) [14]; (figure 3)</td>
</tr>
<tr>
<td>Complications</td>
<td>Discussed in Study</td>
<td>Reference</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
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<td>-----------</td>
</tr>
<tr>
<td>Adjacent deciduous teeth resorption</td>
<td>(This study FIG 1, Fig 3, FIG 4)</td>
<td>(This study FIG 26-FIG 30, FIG 32, FIG 37-FIG 44, FIG 49)</td>
</tr>
<tr>
<td>Adjacent definitive teeth resorption</td>
<td>(This study FIG 5, FIG 6, FIG 16, FIG 21, FIG 33, FIG 34)</td>
<td>(This study FIG 30, FIG 45)</td>
</tr>
<tr>
<td>Relationship with other cranial nerves</td>
<td>(This study FIG 31, FIG 32, FIG 38-FIG 41, FIG 46, FIG 47)</td>
<td></td>
</tr>
<tr>
<td>Deciduous teeth retention [4, 6, 7, 9]</td>
<td>(figures 3-8) [20]</td>
<td></td>
</tr>
<tr>
<td>Definitive teeth retention/impaction [6, 7, 9] [add]</td>
<td>(Figure 3) [18]; (figures 3-8) [20]; (Figure 1) [21]</td>
<td>Displacement of tooth 18 (figures 1, 2) [11]</td>
</tr>
<tr>
<td>Displacement of teeth/malposition [4, 9] [add] [add]</td>
<td>(This study FIG 11, FIG 12, FIG 14)</td>
<td></td>
</tr>
<tr>
<td>Transmigration of teeth</td>
<td>(This study FIG 15, FIG 16, FIG 18, FIG 22, FIG 25)</td>
<td></td>
</tr>
<tr>
<td>Bony expansion [4, 8]</td>
<td>(This study FIG 16, FIG 17, FIG 24)</td>
<td></td>
</tr>
<tr>
<td>[add] thinning of vestibular/buccal cortical bone related to the odontoma</td>
<td>(This study FIG 1, FIG 16, FIG 20, FIG 21, FIG 24)</td>
<td>(This study FIG 29, FIG 31)</td>
</tr>
<tr>
<td>[add] perforation of vestibular/buccal cortical bone related to the odontoma</td>
<td>(This study FIG 6, FIG 7, FIG 16, FIG 20, FIG 24, FIG 34)</td>
<td>(This study FIG 32)</td>
</tr>
<tr>
<td>[add] thinning of lingual/palatine cortical bone related to the odontoma</td>
<td>(This study FIG 9)</td>
<td></td>
</tr>
<tr>
<td>[add] perforation of lingual/palatine cortical bone related to the odontoma</td>
<td>(This study FIG 9)</td>
<td></td>
</tr>
<tr>
<td>Mouth opening limitation [10]</td>
<td>(Figure 1) [10]</td>
<td></td>
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<tr>
<td>Delayed root formation [12]</td>
<td>(figure 1) [12]</td>
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<td>---------------------------</td>
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</tr>
<tr>
<td>[add] Fusion between odontoma and follicular sac of adjacent impacted tooth</td>
<td>(This study FIG 1, FIG 2)</td>
<td></td>
</tr>
<tr>
<td>[add] Oro-antral fistula/communication</td>
<td>(This study FIG 39, FIG 45-FIG 48)</td>
<td></td>
</tr>
<tr>
<td>[add] Maxillary sinus expansion</td>
<td>(This study FIG 40)</td>
<td></td>
</tr>
<tr>
<td>[add] Hyperostosis of maxillary sinus walls</td>
<td>(This study FIG 39, FIG 40, FIG 43-FIG 48)</td>
<td></td>
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<tr>
<td>[add] Thinning/erosion of maxillary sinus walls</td>
<td>(This study FIG 41, FIG 43)</td>
<td></td>
</tr>
<tr>
<td>[add] Perforation of maxillary sinus walls</td>
<td>(This study FIG 42, FIG 44, FIG 46-FIG 48)</td>
<td></td>
</tr>
</tbody>
</table>

Clinical cases presentation for compound odontoma

Maxilla, denticulo-type in canine area

**Fig. 1. Patient n°1. (Patient 14 years-old).** Carestream 9600 CBCT. A-E: Multi-reformatted coronal view. * Impacted tooth n°13. A-E: small arrow: denticulo-type compound odontoma situated between deciduous tooth n°53 and impacted tooth n°13. C-E: thick arrow: external resorption of the tooth n°83 by the odontoma. B-D: association of the odontoma with the follicular sac surrounding the crown of the tooth n°13. C, D: thinning of the vestibular cortical bone by the odontoma.
**Fig. 2. Patient n°1. (Patient 14 years-old).** Carestream 9600 CBCT. Axial view. Thick arrows: denticulo-type compound odontoma thinning the vestibular cortical bone. Dotted arrow: fusion between the odontoma and the follicular sac of the tooth n°13. Thin arrow: close contact between the odontoma and the root of the tooth n°12, without external resorption.

**Fig. 3. Patient n°1. (Patient 14 years-old).** Carestream 9600 CBCT. Multi-reformatted sagittal view. Arrows: denticulo-type compound odontoma between tooth n°53 and tooth n°13 (*). Discontinuous arrow: external resorption of the tooth n°53 by the odontoma. Tooth n°13(*) has a hooked apex and is surrounded by the right maxillary sinus.
Fig. 4. Patient n°1. (Patient 14 years-old). Carestream 9600 CBCT. 3D reconstruction view. Arrows: denticulo-type compound odontoma between tooth n°53 and tooth n°13.

Maxilla, particle-type in premolar area

Fig. 6. Patient n°2. (Patient 20 years-old). Carestream 9600 CBCT. Axial view. Thin arrows: particle-type compound odontoma situated between roots of teeth n°13 and n°14. Thick arrow: thinning of the palatine cortical bone by the odontoma. Thin discontinuous arrow: discrete external resorption of the distal side of the root of the tooth n°13.

Fig. 7. Patient n°2. (Patient 20 years-old). Carestream 9600 CBCT. Coronal view. Arrows: particle-type compound odontoma. Thick arrow: thinning of the palatine cortical bone by the odontoma.
Mandible, denticulo-particle type in anterior area


Fig. 9. Patient n°3. (Patient 39 years–old). Carestream 9600 CBCT. Axial view. Compound odontoma between teeth n°32 and n°33. Thin discontinuous arrow: close contact without external resorption between the odontoma and the distal side of the root of the tooth n°32. Thin arrow: close contact without external resorption between the odontoma and the mesial side of the root of the tooth n°33. Thick arrow: perforation of the lingual cortical bone by the odontoma.
Fig. 10. Patient n°3. (Patient 39 years-old). Carestream 9600 CBCT. Multi-reformatted sagittal view. Arrow: compound odontoma between teeth n°32 and 33. Discontinuous arrow: close contact between the odontoma (denticulo-particle type compound), and the distal side of the root of the tooth n°32.

Mandible, particle-type in anterior area, lingual to canine

Fig. 11. Patient n°4. (Patient 14 years-old). Planmeca 3D Mid. Axial view. Arrow: particle-type compound odontoma on the lingual and distal side of the root of the tooth n°43. Tooth n°43 is in rotation with its mesial face turned toward vestibular side.
Fig. 12. Patient n°4. (Patient 14 years-old). Planmeca 3D Mid. Axial view. Arrow: particle-type compound odontoma on the lingual side of the root of the tooth n°43. Tooth n°43 presents with two roots: vestibular and lingual. Close contact without external resorption between the odontoma and the lingual root of the tooth n°43.

Fig. 13. Patient n°4. (Patient 14 years-old). Planmeca 3D Mid. Axial view. Dotted arrow: particle-type odontoma between the lingual and the vestibular root of the tooth n°43.
Fig. 14. Patient n°4. (Patient 14 years-old). Planmeca 3D Mid. 3D reconstruction view. Arrows: particle-type compound odontoma on the lingual side of the root of the tooth n°43. Rotation of the tooth n°43 with its mesial side turned toward vestibular side. Diastema between the crowns of teeth n°42 and n°43.

Mandible, denticulo-amorphous type in anterior area

Fig. 15. Patient n°5. (Patient 19 years-old). Carestream 9600 CBCT. Pseudopanoramic reformatted view. Arrow: denticulo-amorphous type odontoma between the tooth n°83 and impacted tooth n°43. The tooth n°43 is in transmigration under the apices of roots of teeth n°41 and n°31.
Fig. 16. Patient n°5. (Patient 19 years-old). Carestream 9600 CBCT. Multi-reformatted coronal view through the odontoma. A. Arrow: denticule content of the odontoma. Discontinued arrow: amorphous content of the odontoma. Tooth n°43 is situated close to the basilar cortex of the mandible. B. Thick arrow: denticule content of the odontoma with malformed crown directed inferiorly. Discontinuous thick arrow: amorphous content of the odontoma. Thin arrow: bony expansion and thinning of the vestibular cortex. Thin discontinuous arrow: external resorption of the root of the tooth n°83 by the odontoma. Presence of thinning of the lingual cortical bone by the odontoma lingual to the tooth n°83.
Fig. 17. Patient n°5. (Patient 19 years-old). Carestream 9600 CBCT. Axial view. Discontinuous arrow: amorphous content of the odontoma. Thin arrow: vestibular bony expansion and thinning of the vestibular cortex. Thin discontinuous arrow: odontoma surrounding the root of the tooth n°42 without its external root resorption.

Fig. 18. Patient n°5. (Patient 19 years-old). Carestream 9600 CBCT. Multi-reformatted coronal view. Thick arrow: denticulo-amorphous type odontoma between the roots of the teeth n°83 and n°42. Thin arrow: close relationship between the odontoma and the distal side of the root of the tooth n°42. Impacted tooth n°43 in transmigration, without ankylosis, and at a distance from the apex of the root of the tooth n°41.
Mandible, denticulo-type in anterior area, impaction of canine

Fig. 19. Patient n°6. (Patient 64 years-old). Carestream 9600 CBCT. Pseudopanoramic reformatted view. Arrow: Denticulo-type odontoma between the roots of the teeth n°44 and n°42. Tooth n°43 impacted and vertical without transmigration.

Fig. 20. Patient n°6. (Patient 64 years-old). Carestream 9600 CBCT. Multi-reformatted coronal view. Thin arrow: thinning of the vestibular cortical bone by the odontoma. Discontinuous arrow: thinning of the lingual cortical bone by the odontoma. Thick arrow: perforation of the alveolar bone, and pre-erupted state of the odontoma.
Fig. 21. Patient n°6. (Patient 64 years-old). Carestream 9600 CBCT. Axial view. Denticulo-type odontoma with multiple denticules (*). Discontinuous arrow: external resorption of the mesial side of the tooth n°44 by the odontoma. Thick arrow: advanced periodontitis around the tooth n°34.

Mandible, denticulo-amorphous type in anterior area, transmigration of canine

Fig. 22. Patient n°7. (Patient 23 years-old). Planmeca 3D mid. 3D reconstruction right lateral view of the mandible with threshold selecting dental tissue. Denticulo-amorphous type odontoma (*) between the teeth n°42 and n°44. Tooth n°43 in transmigration along the basilar cortical bone, and with the crown directed toward posterior. Tooth n°43 is replaced on the dental arch by the metallic prosthetic element.
**Fig. 23. Patient n°7. (Patient 23 years-old).** Planmeca 3D mid. 3D reconstruction right lateral view of the mandible. Denticulo-amorphous type odontoma (*) with one of the denticules in inverted position with the crown directed inferiorly.

**Fig. 24. Patient n°7. (Patient 23 years-old).** Planmeca 3D mid. A-F: sagittal view. A, B. Arrows: inverted and horizontal denticule. C, D. Thick arrow: bone expansion of the odontoma to the lingual side. E. Thinning of the vestibular cortical bone by the odontoma, and extension of the odontoma inferiorly. F. Close relationship between the odontoma and the apex of the root of the tooth n°44.
Clinical cases presentation for complex odontoma

Anterior maxilla


Fig. 26. Patient n°8. (Patient 64 years-old). Carestream 9600 CBCT. Multi-reformatted sagittal view. Complex odontoma in the palatine process of the right maxilla. The odontoma is situated apical to the tooth nº13. Partial extension of the complex odontoma in right maxillary sinus (partial extragnathic type).
Fig. 27. Patient n°8. (Patient 64 years-old). Carestream 9600 CBCT. Axial view. Arrow: complex odontoma. Thin arrow: extension of the complex odontoma in right maxillary sinus.

Anterior mandible

Fig. 28. Patient n°9. (Patient 43 years-old). Carestream 9600 CBCT. Multi-reformatted coronal view. Arrow: complex odontoma with close relationship with the apices of the teeth n°41, and n°42.
**Fig. 29. Patient n°9. (Patient 43 years-old).** Carestream 9600 CBCT. Axial view. Thick arrow: complex odontoma between the lingual and vestibular cortical bone in the midsagittal mandibular area. Thin arrow: amorphous component of the complex odontoma. Discontinuous arrow: thinning of the vestibular bone by the odontoma.

**Posterior mandible**

**Fig. 30. Patient n°10. (Patient 27 years-old).** Carestream 9600 CBCT. Multi-reformatted sagittal view. Thick arrow: complex odontoma close to the apex of the root of the tooth n°37. Thin arrow: external resorption of the root of the tooth n°37 by the odontoma.
Fig. 31. Patient n°10. (Patient 27 years-old). Carestream 9600 CBCT. Multi-reformatted coronal view. A-E. Thick arrow: intra-osseous complex odontoma superior to the left inferior alveolar nerve canal (segmented with orange circle). B-D. Thin arrow: thinning of the vestibular cortical bone by the odontoma.

Fig. 32. Patient n°10. (Patient 27 years-old). Carestream 9600 CBCT. Axial view. Thick arrow: complex odontoma positioned close to the lingual side. Thin arrow: thinning of the lingual cortical bone by the odontoma.
Clinical cases presentation in specific situations

Multiple compound odontoma

Fig. 33. Patient n°11. (Patient 43 years-old). Planmeca 3D Mid. Sagittal view of the right maxilla. A, B. 1. Upper situated denticulo-type compound odontoma between the teeth n°15 and n°16. 2. Lower situated denticulo-type compound odontoma between the teeth n°15 and n°16. Thick arrow: external resorption of the distal side of the tooth n°15. Discontinuous arrow: denticulo-type compound odontoma distal to the tooth n°17 in pre-erupted state. B. Discontinuous arrow: denticulo-type compound odontoma distal to the tooth n°17 in erupted state, and presence of impacted tooth n°18 with its root surrounded by the right maxillary sinus. C. Upper denticulo-type compound odontoma at the floor of the right maxillary sinus. Thick arrow: external resorption of the distal side of the tooth n°15 by the upper situated odontoma.
Fig. 34. Patient no. 11. (Patient 43 years-old). Planmeca 3D Mid. Axial view.

A. Arrow: lower situated denticulo-type compound odontoma between the teeth no. 15 and no. 16. Discontinuous arrow: external resorption of the mesio-vestibular root of the tooth no. 16 by the lower situated denticulo-type compound odontoma. Thick arrow: denticulo-type compound odontoma distal and palatine to the tooth no. 17, and in pre-erupted state. B. Arrow: Upper situated denticulo-type compound odontoma between the teeth no. 15 and no. 16. Discontinuous arrow: external resorption of the distal side of the root of the tooth no. 15 by the upper situated denticulo-type compound odontoma. Thick arrow: denticulo-type compound odontoma distal and palatine to the tooth no. 17, and palatine to the crown of the tooth no. 18. C. Arrow: upper situated denticulo-type compound odontoma with close relationship with the right maxillary sinus.
Fig. 35. Patient n°11. (Patient 43 years-old). Planmeca 3D Mid. 3D reconstruction view of the right lateral maxilla. (*) lower situated denticulo-type compound odontoma, (**) upper situated denticulo-type compound odontoma. Arrow: denticulo-type compound odontoma distal to the roots of the tooth n°17, and apical to the crown of the tooth n°18.

Fig. 36. Patient n°11. (Patient 43 years-old). Planmeca 3D Mid. Coronal view. (*) lower situated denticulo-type compound odontoma, (**) upper situated denticulo-type compound odontoma. Arrow: lower situated denticulo-type compound odontoma is in pre-eruptive state. Thick arrow: (**) upper situated denticulo-type compound odontoma at the floor of the right maxillary sinus.
Double extragnathic complex odontoma

Fig. 37. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Coronal view of the anterior maxillary sinus. (*) Anterior complex odontoma inside the left maxillary sinus. Arrow: amorphous tissue component of the complex odontoma. Discontinuous arrow: denticule tissue component of the complex odontoma.
Fig. 38. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Coronal view of the midsection of the anterior complex odontoma (*). Thick arrow: amorphous tissue component of the complex odontoma. Arrow: denticule tissue component of the complex odontoma in the palatine process of the left maxilla. Red arrows: perforations of the lateral wall of the left maxilla by the expansion and eruption of the odontoma. 1. Left suborbital nerve canal surrounded by the complex odontoma. 2. Close relationship between complex odontoma and the left nasolacrimal duct. 3. Thickening of the mucosa around the left middle turbinate and in the left ethmoid sinus cells. 4. Paradoxal left inferior turbinate. 5. Bone spur from nasal septum directed to-ward left, and in contact with the left inferior turbinate. 6. Discrete thickening of the mucosa in the right maxillary sinus. 7. Right zygomatico-maxillary suture.
Fig. 39. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Coronal view of the intermediate area between anterior and posterior complex odontoma (**). Red discontinuous arrow: perforation at the level of the left alveolar bone, and presence of major oro-sinusal fistula. 1. Right uncinate process. 2. Right infundibulum. 3. Right ostium. 4. Absence of left uncinate process, of left infundibulum, and of left ostium. 5. Thickening of the mucosa around the left middle turbinate and in the left ethmoid sinus cells. 6. Hyperostosis of the left zygomaticomaxillary process. Left suborbital nerve canal surrounded by the complex odontoma.
Fig. 40. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Coronal view of the midsection of the posterior complex odontoma (**). Red discontinuous arrow: perforation of the left alveolar bone, and the complex odontoma in eruptive state. Arrow: posterior complex odontoma (**) with amorphous tissue content. 1. Thickening and internal erosion of the left lateral wall of the left maxillary sinus. 2. Thickening of the floor of the left orbit. 3. Thickening of the nasal wall of the left maxillary sinus. 4. Thickening of the mucosa and in the posterior cells of the left ethmoid sinus. 5. Thickening of the mucosa around the left middle turbinate. 6. Transverse expansion of the maxillary sinus due to the presence of the complex odontoma. 7. Decreasing in transversal dimension of the left nasal fossa.
Fig. 41. **Patient n°12. (Patient 69 years-old)**. Planmeca 3D Mid. Coronal view of the posterior area of the posterior complex odontoma. Arrows: amorphous tissue belonging to the posterior complex odontoma. 1. Upper nasal wall missing on the left maxillary sinus. (*) thickening of the mucosa around the left middle turbinate. 2. Thickening of the mucosa in the posterior cells of the left ethmoid sinus. 3. Thinning of the lateral wall of the left maxillary sinus.
Fig. 42. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Axial view of complex odontoma at the level of the floor of the left maxillary sinus. (*) Denticules component of the anterior complex odontoma. (**) Amorphous component of the posterior complex odontoma. Red discontinuous arrows: absence of left lateral wall of the left maxillary sinus with the complex odontoma in eruptive state.

Fig. 43. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Axial view at the midsection of the anterior (*) and posterior (**) complex odontoma. Amorphous and denticule content of the anterior complex odontoma (*). Amorphous only content of the posterior complex odontoma (**). 1. Erosion of the left zygomaticomaxillary process. 2. Hyperostosis of the left zygomaticomaxillary process.
Fig. 44. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Axial view at the upper level of the complex odontoma. (**): Posterior complex odontoma. 1. Left suborbital nerve canal with posterior contact with the posterior complex odontoma (**). 2. Absence of the nasal wall of the left maxillary sinus. 3. Thickening of the mucosa of the left middle turbinate, and obstruction of the left nasal fossa. 4. Hyperostosis of the left lateral wall of the left maxillary sinus. 5. Hyperostosis of the left zygomaticomaxillary process.
**Fig. 45. Patient n°12. (Patient 69 years-old).** Planmeca 3D Mid. Sagittal view close to the nasal wall of the left maxillary sinus. Anterior (*) and posterior (**) complex odontoma. Red discontinuous arrow: perforation of the palatine bone and oro-antral communication. 1. External resorption of the tooth n° 15 by the anterior complex odontoma. 2. Hyperostosis of the posterior wall of the left maxillary sinus. 3. Left great palatine canal.
Fig. 46. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Sagittal view through the midline of both odontoma. (*) Anterior complex odontoma. (**) Posterior complex odontoma. Red discontinuous arrows: perforation of the alveolar bone of the left maxilla, and posterior complex odontoma in eruptive state. 1. Left suborbital nerve foramen and canal surrounded by the anterior complex odontoma. 2. Hyperostosis of the floor of the left orbit. 3. P-Left pterygopalatine fossa.
Fig. 47. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. Sagittal view through the lateral wall of the left maxillary sinus. (*) Anterior complex odontoma. (**) Posterior complex odontoma. Red discontinuous arrows: perforation of the lateral wall of the left maxillary sinus, and posterior complex odontoma in eruptive state. 1. Left suborbital nerve canal surrounded by hyperostotic bone. 2. Hyperostosis of the posterior wall of the left maxillary sinus.
Fig. 48. Patient n°12. (Patient 69 years old). Planmeca 3D Mid. Multi-reformatted sagittal view through both the anterior and posterior complex odontoma. Anterior complex odontoma (*) and posterior complex odontoma (**). Red discontinuous arrow: perforation of the alveolar bone of the left maxilla, and left oro-antral communication. Thick arrows: amorphous content of the complex odontoma. Thin arrows: denticule content of the complex odontoma.
Fig. 49. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. 3D reconstruction of the posterior complex odontoma (**) with its limits underlined with thick arrows. Thin arrows: border between both odontomas.
Fig. 50. Patient n°12. (Patient 69 years-old). Planmeca 3D Mid. 3D reconstruction of the anterior complex odontoma (*) with its limits underlined with thick arrows. 1. Denticule component of the complex odontoma.

Discussion

Odontomas are the most common benign odontogenic tumours with a histologically high degree of differentiation and an excellent biological behaviour. They may occur in two forms: a complex odontoma or a compound odontoma [24]. A complex odontoma looks like an irregular and disorganized mass of tooth tissue and occurs mainly in the premolar-molar region of the upper and lower jaw. On the other hand, a compound odontoma is a conglomerate of numerous small fragments. Many of these fragments are real miniature teeth in which a crown and a root, covered by enamel and cementum, can be clearly distinguished. The number of these tooth-like configurations can vary from a few individuals to several hundred [25]. In this discussion, the radiological features of odontomas will firstly be discussed, followed by the difficulties of diagnosis and why a CBCT classification matrix is of great value. Lastly, the role of CBCT in treatment and treatment planning will be discussed.
Radiologic features

Radiologically, this odontogenic tumour is initially lucent, but with time, it develops small calcifications, which eventually coalesce to form a radio-dense lesion with a lucent rim [26]. Compound odontomas usually contain a radio-opaque mass with irregular margins and tooth-like structure. Compound odontomas present radio-lucid peripheral borders, whereas complex odontomas exhibit unique radio-opacity, sometimes surrounded by a thin radiolucent area [1, 25, 27]. According to the degree of odontoma calcification, three stages of development can be identified: 1) radio-lucid stage lacking calcification of dental tissues, 2) stage with partial calcifications, and 3) radio-opaque stage surrounded by a radio-lucid halo [25, 28]. Orthopantomogram, periapical, and occlusal radiographs are conventional dental radiography techniques which are commonly used for diagnostic purposes. But, CBCT provides several advantages regarding diagnostic and treatment planning because it provides a three-dimensional image of the structural relationships. Images in three planes of sections (axial, sagittal, coronal) make evaluation of anatomical structures more accurate, and 3D reconstruction can play a critical role in diagnosis and surgical planning [1, 2]. Moreover, it provides the determination of the tumour size, density, presence of root resorption, cortical bone expansion, and perforation, in addition to the relationship with adjacent anatomic structures such as the inferior alveolar nerve and adjacent teeth [29]. Both the extent of the lesion and its effects on adjacent structures are better delineated with CBCT. Additionally, the presence of calcifications and cortical perforation are more visible on CBCT versus a panoramic image [2].

Diagnosis

Problems concerning the diagnosis are related to the site (multiple or unique), size and location of the odontoma. The location can be intraosseous, extraosseous (partially or completely) and rarely in soft tissues. [1, 2, 10-12, 15-22] Furthermore, extension of the lesion can be by bony expansion, thinning or perforation of the cortical bone. These extensions are better visible on CBCT [4, 6, 30]. Lastly, the relationship between the odontoma and adjacent teeth and adjacent structures are of importance for the diagnosis [2, 30]. Since CBCT offers a precise position and accurate diagnosis of complex and compound odontomas, this research constructed a classification matrix for complex and compound odontomas [1, 4, 6].

Classification matrix

This open classification matrix for compound and complex odontomas on Table 1 contains 102 boxes. The descriptions for our classification matrix were composed of: 1) Giant odontoma; 2) Quantity; 3) Location within the arch; 4) Location in relation with adjacent teeth; 5) Maxilla location; 6) Mandible location; 7) Type; and 8) Complications. According to our clinical findings (Figures 20, 33, 34, 36) we added two new sub-classifications for “location within in arch”. Pre-erupted state
(perforation of alveolar bone on the dental arch), and partially extragnathic position of odontoma. The “location in relation with adjacent definitive teeth” was also added, based on the same scheme as the location in relation with adjacent deciduous teeth from Teruhisa et al. [23]. Furthermore, we added 7 new sub classifications for description of the position of the odontoma in relation with the definitive tooth. We added mandible and maxilla location separated into anterior, premolar, and molar area that were not present in previous classifications. We added the denticulo-amorphous type according to our clinical findings (Figures 15, 18, 22-25, 42, 43, 45-48, 50). Finally, we added 12 new sub-classifications on complications related to odontomas.

The content of the presented matrix is based on descriptions of odontomas in open-access literature, from authors’ interpretation of figures and illustrations in the open-access selected articles and from own presented cases. The 36 boxes were already illustrated by 23 figures available in open-access literature in Pubmed [7, 10-22]. This article freely provided 50 figures. The open access figures from literature and from this research illustrated 23 boxes. With this pictorial review, this research was able to illustrate itself 30 boxes. In the future, other authors could complete 30 empty boxes, add more types in the same classification or add new (sub)classifications below or inside the existing ones presented in this research.

Analogically, new research could be published in open-access. Therefore, this pictorial review was able to freely provide the readership with a more complete description of complex odontomas, compound odontomas, multiple compound odontomas and double extragnathic complex odontomas on CBCT data in comparison to earlier published studies.

**Treatment and treatment planning**

After surgical removal of odontoma, there is no tendency of recurrence. Nevertheless, it is advisable to always have the surgical specimen examined anatomically because of the rare possibility of an odonto-ameloblastoma. This rare lesion combines the characteristics of an odontoma with those of an ameloblastoma. Treatment is identical to that of an ameloblastoma. According to WHO (2017), odonto-ameloblastoma no longer forms a separate entity but is included in ameloblastoma.

When odontomas extend beyond the alveolar process into the fascial planes, nasal fossae, paranasal sinuses, and orbits, a CBCT can more precisely demonstrate the extent and boundaries of the lesions. For example, a compound odontoma can cause a slight bone expansion that is noticeably different from the more significant bone expansion caused by complex odontoma [31]. Moreover, CBCT imaging allows a 3D visualization that, besides showing the association between lesions, also demonstrates the margins of the connected lesions and their internal architecture, and provides a precise follow-up after surgical removal [2, 32]. A prompt follow-up is essential for evaluation of further development of the permanent dentition at the removal location [2]. Additionally, CBCT imaging provides a detailed assessment of
odontomas and impacted teeth regarding position, distance to associated teeth and adjacent cortex, and occurrence of root resorption. Moreover, in patients with skeletal malocclusion caused by odontoma, the prioritization of treatment is of great importance. If surgical removal of odontoma is postponed, the probability of adjacent teeth impaction, and therefore malocclusion, increases. Also, it can compromise facial growth and cause facial asymmetry [33, 34]. Therefore, early diagnosis regarding impacted tooth is necessary in order to treat the impacted tooth with for example an orthodontic appliance [35].

Conclusion

In conclusion, CBCT offers precise position and accurate diagnosis of complex and compound odontomas, while providing important information on treatment management and follow-up that isn’t apparent on 2D imaging. Therefore, this review presents a CBCT classification matrix for odontomas describing 1) Giant odontoma; 2) Quantity; 3) Location within the arch; 4) Location in relation with adjacent teeth; 5) Maxilla location; 6) Mandible location; 7) Type; 8) Complications. Consequently, this pictorial review can freely provide the readers a classification matrix with a more complete description of complex and compound odontomas using CBCT data published in earlier studies together with our own clinical cases.
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• **Informed consent**: Patients n°4, 7, 11, 12 were exempted from the informed consent according to the ethical committee approval. There was no need for the informed consent for patients n°1-3, 5, 6, 8-10 as all the images were anonymized and no private data were provided allowing the patient’s identification.

**Authors contribution:**

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References


