**VERTICAL ROOT FRACTURES**

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*Diplomate, American Board of Endodontics*
*Endodontist, The Dental Specialists*

**Fractured Teeth**

- Fractures
- Root Fracture
- Longitudinal
  - Vertical Root Fracture
  - Split Root
- Horizontal
- Traumatic Fracture

**New Definitions from 2015!**

- **Root fracture** — A fracture that exists or extends into the root, to include dentin, cementum, and possibly pulpal space, which may progress to or from the enamel.
- **Longitudinal fracture** — A root fracture extending in the axial plane within the tooth.
New Definitions from 2015!

**Longitudinal fracture** — A root fracture extending in the axial plane within the tooth.

**Vertical root fracture** — A fracture in the root whereby the fractured segments are incompletely separated; it may occur buccal-lingually or mesial-distally; it may cause an isolated periodontal defect(s) or sinus tract; it may be radiographically evident.

Are you seeing more cracked teeth and vertical root fractures?

Patients are keeping their teeth longer

Physical anthropologists estimate tooth longevity without modern care to be 30-40 yrs based on enamel wear patterns.

Simon Hillson-Dental Anthropology 1996

Average Life Expectancy USA Circa 1900

Men = 46.3 yrs
Women = 48.3 yrs

Average Life Expectancy USA Circa 2016

Men = 76.6 yrs
Women = 81.5 yrs
Older teeth are more prone to fracture

Age of dentin

Age alone has been shown to be a significant factor in dentin fracture.

Dentin from patients <35 vs >55 shows a 50% reduction in strength of >55

Dentin from patients <35 vs >55 shows 75% reduction in energy required to FX >55

>55 has greater mineral content and avg rate of crack growth 100X that of <35


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Vertical Root Fracture

Etiology/Risk Factors

- Thin roots
- RCT
  - Dehydrated dentin
  - Removing excess dentin
  - Ca(OH)₂, NaOCl, MTA, EDTA
  - Obtura>Lateral cond. > Thermafil
- Excessive internal load
  - Wedging posts
  - Endocal 10
- Occlusal force
Etiologies

Stress from occlusal forces

Etiologies

Stress from occlusal forces
Chan C.P., et al. 1998. JOE

Diagnosis

On average, 10 years after RCT
May mimic periodontal disease or failed RCT
Restorative history
Pain not diagnostic
Diagnosis

Most common signs and symptoms of VRF

Deep osseous defects, especially on buccal aspect of susceptible teeth and roots
- maxillary and mandibular premolars
- mesial roots of mandibular molars
- Coronally located sinus tract


Clinical Features

Radiographic Appearance

Normal 21%
- Apical only 21%
- Apical, lateral, crestal 45%
- Crestal only 10%
- Apical and crestal 3%

**Radiographic Appearance**

“Halo” lesion, perilateral radiolucency, and angular resorption of the crestal bone... indicated a high probability of vertical root fractures in maxillary premolars.

*Tamse et al. 1999 Oral Surg.*

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**Can you see vertical root fractures on CBCTs?**

“0.3-mm voxel resolution images were demonstrated not to be a reliable protocol for the investigation of longitudinal root fractures.”

*Melo et al. Diagnostic ability of a cone-beam computed tomography scan to assess longitudinal root fractures in prosthetically treated teeth J Endod 2010;36:1879–1882*
Can you see vertical root fractures on CBCTs?

“...the presence of cast-gold posts or gutta-percha cones reduced the overall CBCT diagnostic ability...”


How can we improve the visibility of vertical root fractures on CBCTs?

Conclusions

Metal post and gutta-percha = poor visibility
Fiber posts of no root canal material = better visibility
Imaging mode had no influence on the diagnostic ability
low-dose imaging mode (Hi-Speed) recommended


If you can’t see the fracture, what can you see?

[Images of dental X-rays and CT scans]
Conclusion

Digital periapical radiography and CBCT imaging have significant limitations when detecting vertical root fractures in vivo.

CBCT imaging more likely to detect subtle changes in periradicular bone rather than specifically detecting the fracture line.


Some fractures can only be confirmed upon flap reflection


Can root fractures be prevented by using a resin-based obturation material?

Yes


No


Treatment options for vertical root fractures

- Root amputation
- Hemisection
- Extraction
- Repair?

Hemisection

What would you recommend?


Can vertical root fractures be repaired?

Possibly… based on recent case series
21 RCT maxillary single-rooted teeth with VRFs were evaluated
- atraumatic extraction
- fractured fragments adhesively cemented with 4-methacryloxyethyl trimellitate anhydride/methacrylate-tri-n-butyl borane (4-META MMA-TBB) resin cement
- teeth replanted and splinted for 2 weeks
- followed up at 6 and 12 months


Can vertical root fractures be repaired?

Results
- 2 teeth were extracted in 1st month
- Evidence of improved periodontal status and bone healing in other teeth at 12 months


“Teeth even compromised because of periodontal disease or endodontic problems may have a longevity that surpasses by far that of the average implant (Carnevale et al. 1998; Hardt et al. 2002; Lang and Zitzmann 2012; Salvi et al. 2014; Klinge et al. 2015).”

Giannobile and Lang, JDR 2016 Vol 95, 5-6.

Dental MRI

Center for Magnetic Resonance Research (CMRR) at UMN

Previous Demonstrations - Proof of Concept:
- Ability to obtain MRI signal from densely mineralized tissue
- Visualize small structures within teeth (cracks & fractures)
- Ability to acquire in-vivo images of teeth
- Development of an intraoral radiofrequency coil
- Improved image resolution, scan times, tissues of interest
Thank you!

ADVANCES IN CLEAR ALIGNER THERAPY

James J. Hulwi, DMD

October 4, 2016

Today’s Agenda

- Types of orthodontic treatment
- Case selection
  - Sagittal
  - Transverse
  - Vertical
- Case studies
- Benefits of clear aligner therapy
What is clear aligner therapy?

- Series of clear, removable aligners
- Each aligner contains sequential movements (0.25mm)
- These movements are determined by the clinician’s diagnosis and treatment plan
- Movements are shown on a 3D virtual model
Case Selection

Sagittal Dimension

Molar & Cuspid Relationship

Class I  Class II  Class III

Class II correction

Elastic Hook  Button Cutout
Sagittal Dimension

- Class II correction

![Images of dental conditions]

Vertical Dimension

- Normal
- Edge to Edge
- Deep Bite
- Open Bite

Management of the deep bite
- Control of anchorage
- Premolar extrusion

![Images of dental conditions]
Vertical Dimension

- Management of the deep bite
  - Posterior disocclusion

[Images of teeth showing posterior disocclusion]

Vertical Dimension

- Management of the deep bite

[Images of teeth showing different bite types]

Transverse Dimension

- Arch form
  - U Shape
  - V Shape
  - Square
  - Omega
Transverse Dimension

- Arch development and expansion

Case Studies
Case 1

- 33 year old female

Case 2

- 56 year old male
Case 2
- 56 year old male

Case 3
- 21 year old female

Case 3
- 21 year old female
Case 3

- 21 year old female

Benefits of clear aligners

- Appearance
- Comfort
- Lifestyle
- Hygiene
Thank you!

Questions?
How many implants are placed every year in the US?

Increase in Implant Placement from 2013-2017 US Dental implant market

<table>
<thead>
<tr>
<th>YEAR</th>
<th>UNITED STATES</th>
<th>GROWTH (%)</th>
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<tbody>
<tr>
<td>2013</td>
<td>2,208,236</td>
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<tr>
<td>2014</td>
<td>2,309,819</td>
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<td>2015</td>
<td>2,432,014</td>
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<tr>
<td>2016</td>
<td>2,573,539</td>
<td>5.8</td>
</tr>
<tr>
<td>2017</td>
<td>2,730,788</td>
<td>6.1</td>
</tr>
</tbody>
</table>

From iData Research Inc., 2015

What are peri-implant diseases?
Peri-implant diseases

- Per-implant mucositis: a disease in which the presence of inflammation is confined to the soft tissues surrounding a dental implant with no signs of loss of supporting bone following initial bone remodeling during healing.

- Peri-implantitis: an inflammatory process around an implant, which includes both soft tissue inflammation and progressive loss of supporting bone beyond biological bone remodeling.

What is the prevalence?

Prevalence of Peri-implant mucositis and Peri-implantitis

- Prevalence of peri-implant mucositis: 33% - 66% (Tomasi and Derks J Clin Periodontol. 2012), 19% - 65% (mean 43%) (Derks & Tomasi 2015)

- Prevalence of peri-implantitis: 8.9% - 47% of the subjects studied (Tomasi and Derks J Clin Periodontol. 2012), 1% - 47% (mean 22%) (Derks & Tomasi 2015)
What are the etiologies and pathogenesis?

Peri-implant mucositis

- A cause-and-effect relationship between bacterial plaque and developing mucositis was demonstrated for oral implants. (Pontoriero et al. 1994, Salvi et al. 2012)
- Patients refrained from oral hygiene for 3 weeks, after which time both the teeth and the implants developed gingivitis and mucositis.
- The condition is reversible. The tissues were returned to health after regular oral hygiene was resumed.

Peri-implantitis

- Peri-implant mucositis is the precursor of peri-implantitis.
- Peri-implant mucositis is not peri-implantitis.
- Peri-implantitis like periodontitis, occurs primarily as a result of the bacteria insult and subsequent host immune response.
Peri-implantitis lesion:
- tissue destruction were more pronounced
- size of the ICT (infiltrated connective tissue) in the connective tissue was larger
- in contrast to periodontitis lesions, reached the bone crest.
- No self limiting process

Periodontitis lesion:
- “self-limiting” process occurred in the periodontal tissues after ligature removal

(adapted from Lindhe et al., Clinical Oral Implants Research 1992)

- It is suggested that peri-implantitis-associated bone loss varies between subjects and is, in most cases, characterized by a non-linear progression, with the rate of loss increasing over time.

What are the risk factors?
Risk factors (AAP 2013)

- Previous periodontal disease
- Poor plaque control/inability to clean
- Residual cement
- Smoking
- Genetic factors
- Diabetes
- Occlusal overload
- Cardiovascular disease (Renvert et al. 2014)
- Inadequate gingiva (Gobbato et al. 2013, Lin et al. 2014, Brito et al. 2014)
- Poor prosthetic fit/micromotion (Bergmann et al. 2014, Gigandet et al. 2014)
- Presence of foreign material/titanium (Linkevicius et al. 2013, Wilson et al., 2015)
- Reuse of healing abutments (Wadhswani et al. 2015)

How to diagnose?

Diagnosis: Probing, Bleeding, Suppuration

- Initial probing of the implant should be done once the final restoration has been installed. A change of probing depth is more important than the initial findings.
- Gentle probing resulting in bleeding suggests the presence of soft tissue inflammation. Absence of BOP around implants would indicate healthy peri-implant tissues.
- Pus formation is always a sign of infection with active tissue destructive processes taking place.
**Diagnosis: Radiograph, Mobility**

- Periapical radiographs of the implant following placement and then following the prosthesis installation should function as the baseline. The radiograph at restoration is also used to see if the cement is completely removed.
- Subsequent radiographs should also be taken in the event of soft tissue attachment level changes or significant tone and color change.
- Mobility

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**Classification and Prognosis of peri-implantitis**

*(From & Rosen 2012)*

**Classification of Peri-implantitis**

- **Mild**
  - PD $\geq 4$ mm
  - Bleeding and/or purulent discharge on gentle probing*
  - Bone loss $< 25\%$ implant length**

- **Moderate**
  - PD $\geq 6$ mm
  - Bleeding and/or purulent discharge on gentle probing*
  - Bone loss 25-50\% implant length**

- **Advanced**
  - PD $\geq 8$ mm
  - Bleeding and/or purulent discharge on gentle probing*
  - Bone loss > 50\% implant length**

* BOP and/or suppuration on 2 or more aspects of the implant were selected as the markers of inflammation.
** Bone loss was measured on most recent radiograph and compared with radiograph taken at the time of prosthetic loading.
## Per-implant Diseases Prognosis
(Decker et al. 2015)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Favorable</th>
<th>Favorable</th>
<th>Questionable</th>
<th>Unfavorable</th>
<th>Hopeless</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ BOP/ Suppuration</td>
<td>▪ PD ≥ 4mm</td>
<td>▪ No bone loss</td>
<td>▪ No mobility</td>
<td>▪ PD ≥ 4mm</td>
<td>▪ BOP/ Suppuration</td>
</tr>
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<td>▪ No mobility</td>
<td>▪ PD ≥ 4mm</td>
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<td>▪ No mobility</td>
<td>▪ PD ≥ 4mm</td>
<td>▪ BOP/ Suppuration</td>
</tr>
<tr>
<td>▪ No mobility</td>
<td>▪ PD ≥ 4mm</td>
<td>▪ Bone loss: 1/4-1/2 implant</td>
<td>▪ No mobility</td>
<td>▪ PD ≥ 4mm</td>
<td>▪ BOP/ Suppuration</td>
</tr>
<tr>
<td>▪ No mobility</td>
<td>▪ PD ≥ 8mm</td>
<td>▪ Bone loss: &gt;1/2 implant</td>
<td>▪ No mobility</td>
<td>▪ PD ≥ 8mm</td>
<td>▪ BOP/ Suppuration</td>
</tr>
</tbody>
</table>

### Diagnosis
- Peri-implant mucositis
  - Early
  - Moderate
  - Advanced peri-implantitis

### Recommendations
- Non-surgical therapy
  - Non-surgical therapy
  - Surgical treatment
  - Extraction of develop site
  - Extraction

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### How to manage the peri-implant diseases?

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### Prevention
- Oral infections such as existing periodontal disease have to be treated before implant therapy. (Pjetursson et al. 2012)
- The patient should be motivated to perform an adequate level of plaque control on a regular basis
- Cleanable reconstructions
- Periodontal maintenance:
  - When patient did not completely adhere to PM, they had a higher rate of implant failure. (Roccuzzo et al. 2010)
  - Periodontal maintenance is a key factor in controlling reinfecion and limiting biologic complications.
Therapeutic strategies
(Lang et al. 2000 Clin Oral Impl Res)

- Cumulative Interceptive Supportive Therapy: It provides a progressive algorithm of treatment and is used as a sequence of procedures with increasing antibacterial potential.
- There are generally accepted quantifiable clinical parameters that can be used as monitors. These clinical parameters include:
  - Plaque
  - Bleeding upon gentle probing
  - Suppuration
  - Probing depth
  - Radiographic bone loss

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CIST
(Lang et al. 2000 Clin Oral Impl Res)

<table>
<thead>
<tr>
<th>PD &lt;3mm</th>
<th>Presence of plaque and BOP (+)</th>
<th>No treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD 4.5mm</td>
<td>Absence of plaque and BOP (-)</td>
<td>Mechanical debridement, polishing and scaling</td>
</tr>
<tr>
<td>PD &gt; 5mm</td>
<td>BOP +, no bone loss</td>
<td>Antiseptic CHX rinse or gel 2x daily for 3-4 weeks</td>
</tr>
<tr>
<td></td>
<td>BOP +, bone loss &lt;2mm</td>
<td>Systemic or local antibiotics therapy</td>
</tr>
<tr>
<td></td>
<td>BOP +, bone loss &gt; 2mm</td>
<td>Resective or regenerative surgery</td>
</tr>
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</table>
**Protocol A (mechanical cleaning)**

- PD <3 mm, plaque and/or calculus (+). BOP (+) and (-).
- Nonsurgical mechanical debridement of the implant surface, focusing on both plaque and calculus.
- Instruments: plastic curettes, carbon fiber–reinforced plastic curette, prophy brush/cup, sonic or ultrasonic-driven polyetheretherketone plastic tip [PEEK], air polishing with glycine powder.

**CIST**

(Lang et al. 2000 Clin Oral Impl Res)

| PD <3mm | Presence of plaque and BOP (+) | No treatment | A |
| PD 4.5mm | BOP +, no bone loss | Mechanical debridement, polishing and scaling | B |
| PD >5mm | BOP +, bone loss ≤2mm | Antibiotic CHX rinsing or gel 2x daily for 3-4 weeks | C |
| | BOP +, bone loss >2mm | Systemic or local antibiotics therapy | |
| | | Reactive or regenerative surgery | D |

**Protocol B (antiseptic therapy)**

- PD from 3 to 5 mm, or greater than 5 mm with BOP and without radiographically identifiable bone loss around the implant.
- Rinse with 0.1% to 0.2% chlorhexidine digluconate 10ml for 30 seconds twice a day for 3 to 4 weeks, or chlorhexidine gel locally application.
Peri-implant mucositis:
❖ Mechanical, antiseptic and antibiotics steps are effective
   (Heitz-Mayfield et al. 2011)

Peri-implantitis:
❖ Non-surgical therapy was not found to be effective. Adjunctive chlorhexidine application had only limited effects on clinical and microbiological parameters. However, adjunctive local or systemic antibiotics were shown to reduce bleeding on probing and probing depth. (Rainert et al. 2006)
❖ Nonsurgical treatment of peri-implantitis shows limited improvement in clinical parameters. (Faggion et al. 2014)

Protocol C (antibiotic therapy)
● PD greater than 5, BOP, and an identifiable bone defect up to 2 mm loss on radiograph.
● Antibiotic treatment is typically used during the last 10 days of antiseptic treatment per protocol B. Systemic antibiotic options include amoxicillin, metronidazole, clindamycin, augmentin, tetracycline, bactrim, and ciprofloxacin (or a combination of the above) with no clear preferred therapy. (Heitz-Mayfield & Mombelli 2014)
● Local antibiotic delivery methods (tetracycline periodontal fibers and minocycline microspheres) appear to have similar effectiveness as systemically administered antibiotics. (Froum 2000)
CIST (Lang et al. 2000 Clin Oral Impl Res)

PD <3mm
- Absence of plaque and BOP (-)
  - No treatment

PD 4.5mm
- Presence of plaque and BOP (+)
  - Mechanical debridement, polishing and scaling

PD >5mm
- BOP +, no bone loss
  - Antiseptic CHX rinse or gel 2x daily for 3-4 weeks
- BOP +, bone loss ≤2mm
  - Systemic or local antibiotics therapy
- BOP +, bone loss >2mm
  - Resective or regenerative surgery

Protocol D (Regenerative or Resective)

❖ Severe peri-implantitis defects. Per the protocol, it involves regenerative or resective therapy only if infection is controlled successfully, as evidenced by an absence of suppuration and reduced edema.
❖ The efficacy of 4 surgical procedures (access flap and debridement alone, surgical resection, regeneration with bone grafts, and guided bone regeneration) were studied in a systematic review of peri-implantitis treatment option outcomes. (Chan et al. 2014)
❖ In short-term (3mo-63 mo) follow ups, these procedures yielded a 2-3mm PD reduction. A mean 2-mm RBF (radiographic bone fill) was obtained with regenerative procedures. The regenerative procedures using bone graft materials in combination with barrier membranes might be more effective. However, there is a lack of high quality comparative studies to support this statement.

Regeneration technique (Froum et al. A consecutive series of 51 treated implants with 3-7.5 year follow up 2012)

The “7 essential factors” identified included:
❖ 1. Flap access to ensure adequate blood supply
❖ 2. Surface decontamination
❖ 3. Defect debridement, using a biologic agent on implant surface
❖ 4. Defect fill, using freeze-dried bone allograft (FDBA) and/or anorganic bovine bone
❖ 5. Coverage, using absorbable membrane or a subepithelial connective tissue graft
❖ 6. Coronal positioning of flaps, providing complete coverage of membrane/graft
❖ 7. Professional maintenance (2-3 months) and excellent homecare
Surface decontamination:
All techniques/agents have shown to be equally effective. The most effective treatment to detoxify the implant surface has not been identified.
Saurez et al. Implant Dentistry 2013

Regenerative Approach  Stuart J. Froum, September 2014 (Compendium of continuing education in Dentistry)

Regenerative Approach - 7 years post-surgery
Froum, September 2014
(Compendium of continuing education in Dentistry)
A Regenerative Approach to the Successful Treatment of Peri-implantitis: A Consecutive Series of 170 Implants in 100 Patients with 2- to 10-Year Follow-up. (Froum et al. 2015)

❖ BOP was eliminated in 91% of the treated implants.
❖ PD reduction averaged 5.10 mm
❖ Bone level gain averaged 1.77 mm
❖ Soft tissue marginal gain averaged 0.52 mm.
**Per-implant Diseases Prognosis**  
*(Decker et al. 2015)*

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<td>BOP/Suppuration</td>
<td>PD ≥ 4mm</td>
<td>Bone loss &gt;1/2 implant</td>
<td>Mobility</td>
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<table>
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<tr>
<th>Diagnosis</th>
<th>Early peri-implantitis</th>
<th>Moderate peri-implantitis</th>
<th>Advanced peri-implantitis</th>
<th>Advanced peri-implantitis</th>
</tr>
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<tbody>
<tr>
<td>Therapy</td>
<td>Non-surgical therapy</td>
<td>Surgical treatment</td>
<td>Extraction</td>
<td>Extraction</td>
</tr>
</tbody>
</table>

**Treatment outcomes in patients with peri-implantitis in a periodontal clinic: a retrospective study**  
*(Lagervall & Jansson et al. 2013)*

- **M & M**: A retrospective longitudinal study on a referral population. The study included 382 implants with peri-implantitis in 150 patients.
- **Conclusion**: The effectiveness of the peri-implantitis therapy was impaired by severe periodontitis, severe marginal bone loss around the implants, poor oral hygiene and low compliance.

**Explantation**

- Explantation may also be necessary if the periimplant infection has advanced to a degree where it cannot be controlled by the therapeutic protocols proposed above.
- If a previously osseointegrated oral implant is clinically mobile, explantation is mandatory.

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(Adapted from Froum et al. Compendium 2011 (32):7)
Conclusion

- The best approach is to prevent the problem
  - Treat oral infection such as existing periodontal disease
  - Cleanable reconstructions
  - Effective daily plaque control
  - Periodontal maintenance
- Early diagnosis and intervention will contribute to more effective management.
- Identify the potential risks to avoid the complications.
- Nonsurgical therapy and reinforcement of the oral hygiene should be performed before the surgical therapy is applied.
- Surgical therapy provides the access to degranulate the inflamed tissues and to decontaminate and/or modify the implant surface and to regenerate the bone around the implant.

**Treatment workflow chart**

<table>
<thead>
<tr>
<th>Nature of the implant related complications</th>
<th>Remove or correcting risk factors/contributing factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peri-implant mucositis</td>
<td>Mechanical +/- antiseptic / antibiotic</td>
</tr>
<tr>
<td>Peri-implantitis</td>
<td>Evaluation</td>
</tr>
<tr>
<td>Inflamed peri-implant tissue</td>
<td>Inflamed tissue with &lt;2mm bone loss</td>
</tr>
<tr>
<td>Early</td>
<td>Early &lt;25% bone loss</td>
</tr>
<tr>
<td>Flap, surface decontamination, repopulation</td>
<td>Antibiotics and antimicrobial mouthrinse</td>
</tr>
<tr>
<td>Evalution</td>
<td>Peri-implant site development</td>
</tr>
<tr>
<td>Periodontal maintenance</td>
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</table>
Thank You