A long term prospective study of an orthodontic bone achor.

Valerie Nols

Promotor: Prof. Dr. Guy De Pauw
De auteur(s) en de promotor geven de toelating deze Masterproef voor consultatie beschikbaar te stellen en delen ervan te kopiëren voor persoonlijk gebruik. Elk ander gebruik valt onder de beperkingen van het auteursrecht, in het bijzonder met betrekking tot de verplichting uitdrukkelijk de bron te vermelden bij het aanhalen van resultaten uit deze Masterproef.

Datum

(Handtekening student(en)) (Handtekening promotor)

(Naam student) (Naam promotor)
Voorwoord

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Valerie Nols, Gent, 27 april 2011
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I. Abstract

Doel

De hoofdvraag van deze studie is of onmiddellijke belasting van het orthodontisch bot anker (OBA) meer falingen veroorzaakt dan late belasting. Het bijkomende doel was om de impact van verschillende variabelen op het success van OBA’s vast te leggen.

Materiaal en Methode

In een prospectieve studie werden 61 patiënten (37 ♀, 24 ♂) consecutief orthodontisch behandeld met behulp van orthodontische botankers, meer bepaald miniplaatjes ook Orthodontic Bone Anchors genoemd (OBA’s). In totaal werden 106 OBA’s geplaatst door een en dezelfde Mond Kaak en Aangezichts chirurg gedurende een periode van 5 jaar (2001-2006). Een onafhankelijke evaluator heeft de prospectief bepaalde parameters geanalyseerd en vergeleken. Deze parameters zijn: geslacht, leeftijd (jonge leeftijdsgroep <16 jaar vs volwassen leeftijdsgroep ≥16 jaar), type belasting ( immediate belasting of late belasting), kaak, locatie, fixatie schroeflengte, complicaties en orthodontische indicaties. Ook werd op het moment van verwijderen van het botanker klinische bevindingen genoteerd zoals stabiliteit van het miniplaatje en de fixatie schroeven, mogelijke infectie van de weke weefsels en/of het bot rond de fixatieschroeven, gingivarecessies die 1 of meerdere fixatieschroeven blootleggen, bot-overgroei over het miniplaatje en/of de fixatie schroeven.

Succes van het OBA werd gedefinieerd als de capaciteit om de functie van verankering te handhaven gedurende de gehele orthodontische behandeling. Vroegtijdig verwijderen van het OBA omwille van infectie, ernstige mobiliteit of pijn werd als faling beschouwd.

De associaties tussen de verschillende variabelen werd door middel van de Fisher’s exact test onderzocht. Succes en complicaties werden verder geëvalueerd door multivariate regressie analyse toe te passen met significantie niveau p= 0.05.

Resultaten

Het succes percentage van de OBA’s in deze studie was 93.3%. In totaal werden 7 (6.7%) botankers vroegtijdig verwijderd. Het type belasting ( onmiddellijk of laat) beïnvloedde de faling niet. Er werd een statistisch hogere faling in de onderkaak opgemerkt (p= 0.024) en
anterieur geplaatste OBA’s vertoonden een significant hogere falings dan posterieur geplaatste OBA’s (p= 0.034). Tenslotte werden meer falings in de jonge leeftijdsgroep dan in de volwassen leeftijdsgroep aangetroffen (p= 0.02).

**Conclusie**

Controle over verankering is essentieel voor een successvol en stabiel orthodontisch resultaat. Volgens de bevindingen in deze studie zijn OBA’s betrouwbare supplementaire behandelingselementen om absolute verankering te bekomen. Onmiddellijke belasting van het OBA veroorzaakte geen hogere falings ratios dan late belasting. Leeftijd, kaak en de positie (anterieur of posterieur) speelden een belangrijke rol in het succes van de OBA’s.
II. Algemene Inleiding

Orthodontische verankering

De term orthodontische verankering werd geïntroduceerd door Angle in 1907 en later gedefinieerd door Ottofy in 1923 als de aard en mate van weerstand die geleverd moet worden door een anatomische eenheid om gewenste tandverplaatsingen tot stand te brengen zonder ongewenste reciproque tandverplaatsingen. Elke kracht kan opgesplitst worden in een actiekracht en een even grote, maar tegengestelde reactiekracht volgens de derde wet van Newton.

Verankeringspotentieel van tanden volgens Diedrich (1993), wordt beïnvloed door verschillende factoren zoals de grootte van de worteloppervlakte, de hoogte van de parodontale aanhechting, de densiteit en structuur van het alveolair bot, de turn-over snelheid van de parodontale weefsels, de spieractiviteit, de occlusale krachten, de craniofaciale morfologie en de aard van de geplande tandbeweging. (1) Deze ‘biologische’ verankering kan verhoogd worden door selectief momenten en krachten te wijzigen om zo de inclinatie en torque van de anker tanden in te stellen. (2-4) In vele gevallen is dit onvoldoende om nadelige neveneffecten tegen te gaan. Verschillende orthodontische apparaten werden ontwikkeld om de reactiekrachten zo goed mogelijk op te vangen en zo dentale verankering in te stellen, zoals extra- orale tractie (headgear, facial mask) of intermaxillaire apparaten (Herbst, Forsus, etc) en intermaxillaire elastieken. Deze laatste 2 voorbeelden veroorzaken vaak ongewenste neven effecten zoals protrusie en gingivale recessie van de incisieven in de ondertandboog, wortelresorpties en soms ook kanting van het occlusale vlak. Nog een beperking is dat de perfecte medewerking van de patiënt vereist is en dat deze apparaten vaak niet continu gedragen worden. Een palatale bar of een linguale boog bieden verankering door de molaren te blokkeren zonder coöperatie van de patiënt. Al deze conventionele verankerings systemen kunnen geen complete verankering bieden in alle 3 dimensies. Daarom is de interesse in skeletale verankering de laatste 20 jaar in de orthodontie enorm toegenomen, ook al werd dit reeds voor meer dan 60 jaar bestudeerd. (5-7)
De enige mogelijkheden om absolute verankering te bekomen is het gebruik van geankyloseerde tanden of skeletale verankering. Geankyloseerde tanden, net als implantaten, bieden een perfecte weerstand en een absolute verankering doordat ze (gedeeltelijk) in direct contact staan met het bot en geen parodontaal ligament bezitten.(8-10) Er bestaan enkele studies die opzettelijk melkelementen of definitieve elementen lieten ankyloseren om absolute verankering te bieden.(11-13) Dit kan in de praktijk zelden worden toegepast aangezien de meeste patiënten adolescenten of volwassenen zijn die geen melkelementen meer bevatten. Daarenboven kunnen ankylotische elementen interfereren met de eruptie van de definitieve tanden en ook een alveolair botdefect veroorzaken daar deze elementen niet mee erupteren met de omringende tanden.

Dentale implantaten

Dentale implantaten werden in eerste instantie gebruikt voor absolute skeletale verankering in de orthodontie. Het principe van osseointegratie beschreven door Bränemark et al. in 1970 zorgt voor stabiliteit van het implantaat. Een limitatie van het gebruik van deze implantaten in de orthodontie is dat deze zich gedragen als geankyloseerde tanden: ze erupteren niet en de verticale ontwikkeling van het alveolaire bot wordt verhinderd.(8, 14, 15) Daarom is het gebruik van deze implantaten beperkt tot volgroeide patiënten. Daarenboven kunnen ze enkel geplaatst worden in edentate zones, meer bepaald bij patiënten die pre-prothtische orthodontie nodig hebben. Vermits de meeste patiënten adolescenten zijn met een volledige dentitie is er zelden voldoende ruimte in de alveolaire boog voor het plaatsen dentale implantaten. Daarom werd op zoek gegaan naar alternatieve mogelijkheden in insertiezones buiten de tandboog en naar andere tijdelijke skeletale verankering designs. Er werden tal van tijdelijke skeletale verankerings systemen voor orthodontische doeleinden ontwikkeld en beschreven in de literatuur.
Temporary Anchorage Devices

De term Temporary Anchorage Device (TAD) werd geïntroduceerd door Daskalogiannakis in 2000. TAD’s zijn apparaten die tijdelijk gefixeerd worden op het bot met als doel de orthodontische verankering te optimaliseren en de eerder vermelde limitaties van traditionele orthodontische verankeringstechnieken te overbruggen.(16) TAD’s bieden de mogelijkheid om een constante kracht in stand te houden zonder dat er veel patiënt coöperatie nodig is. Ze kunnen orthodontische en orthopedische verplaatsingen toelaten die vroeger als zeer moeilijk of zelfs onmogelijk werden gepercipieerd.(17-19) De TAD’s kunnen als directe verankering gebruikt worden wanneer de krachten rechtstreeks op het anker aangrijpen of als indirecte verankering wanneer het botanker dient om bepaalde anker tanden te stabiliseren en zo weerstand te bieden tegen de reactiekrachten.(20) De indicaties kunnen puur orthodontisch zijn en absolute verankering bieden bij tandverplaatsingen. Daarenboven kunnen de TAD’s ook gebruikt worden voor orthopedische doeleinden zoals protractie van de maxilla bij jonge patiënten met een klasse 3 skeletale groeipatroon.(21, 22) Wanneer het orthodontische of orthopedische doel bereikt is worden de TAD’s verwijderd.

Retromolaar- en palatale implantaten

Aangezien er bij patiënten met een volledige dentitie zelden voldoende ruimte is in de alveolaire boog om dentale implantaten te plaatsen, werd op zoek gegaan naar andere mogelijke insertiezones buiten de tandboog zoals de retromolaar zone of het palatum. (23, 24) Deze implantaten zijn duur en behoeven een lange helingsperiode van minstens 2 maanden voor ze belast kunnen worden, om osseo-integratie toe te laten. Ze hebben gelimiteerde toepassingsmogelijkheden omwille van hun locatie en bieden enkel indirecte verankering. Deze beperkingen hebben gezorgd voor de ontwikkeling van andere vormen van skeletale verankering zoals Miniscrews en miniplates (beter gekend als miniscrews en miniplates). (25-28) Deze zijn goedkoper, kleiner en geschikt voor verschillende locaties in de boven- en onderkaak. Aangezien hun stabilititeit voortkomt uit mechanische ‘interlock’ met het bot en niet uit osseo-integratie, is de helingsperiode voor de kracht applicatie aanzienlijk verkort en is de ingreep voor verwijdering gemakkelijker en minder ingrijpend.(25, 29-31)
Miniscrews

De eerste klinische applicatie van miniscrews vond plaats in 1983 door Creekmore and Eklund.(5) Pas in de jaren ‘90 kwam er meer interesse voor en werd deze TAD verder uitgewerkt door Kanomi, Costa en vele anderen.(25, 32, 33) Miniscrews kunnen overal in de orale caviteit geplaatst worden zolang er voldoende bot voorhanden is (ongeveer 3,5 mm). De plaatsingsprocedure is minimaal want vereist geen flap elevatie. Onmiddellijke belasting is mogelijk daar de Miniscrews ontwikkeld zijn om primaire stabiliteit te bekomen door corticale stabilisatie.

Miniplates

Orthodontische botankers (OBA’s), ook miniplates genoemd, komen voort uit de titanium osteosynthese platen die in cranio-maxillo-faciale chirurgie gebruikt worden voor het fixeren van de botsegmenten na een orthognathische ingreep of bij aangzichts fracturen. De OBA’s werden voor het eerst geïntroduceerd door Michelet et al. in 1973.(34) Deze miniplates werden voor het eerst gebruikt in 1985 voor orthodontische doeleinden door Jenner and Fitzpatrick.(27) Ze plaatsten een plaatje met 4 fixatieschroeven in de ramus om een molaar in de onderkaak te distaliseren. De interesse voor het gebruik van miniplates nam sterk toe na een aantal aanpassingen van het design. Vooral door het toevoegen van een extentie arm, die zich door de vaste gingiva projecteert en orthodontische elementen bevat voor krachtapplicatie.(35, 36) Het punt van krachtapplicatie is dichtbij de tandboog gesitueerd, terwijl de schroeven verder verwijderd zijn van de tanden wat interferentie met de wortels en dus ook met de tandbeweging vermijdt. OBA’s kunnen overal op het buccale botoppervlak geplaatst worden op voorwaarde dat deze een adequate minimum dikte bezit. De meest benutte zones in de onderkaak zijn de symphyse, de anterieure en posterieure corpus en de ramus. In de bovenkaak wordt vooral het os zygomaticum en de paranasale zone benut maar de miniplates worden soms ook in het palatum geplaatst.(37, 38) De voordelen voor dit type botverankering zijn een lange geschiedenis van biocompatibiliteit, grote verscheidenheid in vorm en grootte en weinig risico om zenuwen of wortels te beschadigen dankzij hun insertiezone. Een nadeel is dat er 2 ingrepen nodig zijn voor plaatsen en verwijderen met
incisie en flap-elevatie wat de mogelijke postoperatieve pijn en zwelling kan veroorzaken. (39, 40)

Deze Masterthesis handelt over Orthodontische botankers (OBA’s), meer bepaald miniplates. De hoofdvraag van deze studie is: ‘Vertonen immediaat belaste botankers meer falingen dan laat belaste botankers?’ De impact van verschillende variabelen op het succes van een OBA werd ook uitgebreid bestudeerd. De vraagstelling wordt verder beschreven in de literatuurstudie.
III. Literature study

A literature search was carried out to identify English language articles treating the subject of orthodontic bone anchors also known as miniplates. While skeletal orthodontic anchorage is a rather recent subject, no limitation in time was set. Medline, PubMed and Cochrane Library were searched until March 2011 based on the following search terms: orthodontic bone anchorage, temporary anchorage device, skeletal orthodontic anchorage, miniplate, bone plate, and zygoma anchor. The criteria for inclusion were: clinical human studies, a minimum sample of 20 Orthodontic Bone Anchors (OBA’s) and review articles. In some cases not only miniplates were studied but a combination of different Temporary Anchorage Devices (TAD’s) such as palatal implants and miniscrews. (35, 41-47) This was not a reason for exclusion. Additional articles discussing the success and failure rate of the previously mentioned TAD’s were reviewed in order to be able to compare the orthodontic reliability of these treatment modalities with OBA’s. More emphasis was put on miniscrews while they are used as fixation screws for the miniplates. (26, 48-59) The titles and abstracts of all potentially relevant articles were reviewed. Full text of all relevant articles and those with ambiguous titles and abstracts were collected and reviewed. The search was augmented by screening the reference citations of each identified article for additional articles that might have been missed by the electronic search. A total of 51 relevant articles were identified of which 9 reviews and only 1 systematic review. (43, 46, 60-66) In the Cochrane database of Systematic Reviews no review was found that matched the inclusion criteria. There were 16 articles that specifically examined the success rate of OBA’s or that of several TAD’s (Table 1). This literature review extensively examines the factors influencing failure, the different success rates and describes the orthodontic applications for OBA’s. A direct comparison of the failure or success rates of different studies is difficult and needs to be addressed with precaution because of the differences in study design, screw and/or plate design, and insertion technique. Therefore it is important not to lose sight of the clinical relevance of a statistical correlation. Statistical significance doesn’t always mean that something is of great clinical relevance.

TAD’s provide anchorage that is not tooth-borne because they are attached to the surrounding bone. As a result, unwanted reciprocal tooth movements involving the surrounding teeth are totally avoided. Other advantages of these devices include the following: no or minimal reliance on existing dentition; less dependent on patient compliance; continuous rather than
intermittent force; surgical procedures are necessary but are rather simple in most conditions; force may be applied very soon or immediately after placement while devices require mechanical stability instead of osseointegration; the devices are easily removed.

The anchorage applied may be considered direct or indirect (Fig. 1 and 2). Direct techniques are those that apply force directly from the anchor to the segment or tooth that is to be moved. Indirect techniques connect the anchor device to the segment of teeth that requires additional anchorage so that more traditional mechanics can be used in the area. Rather than an active elastic connection between the anchor and the archwire, indirect anchorage involves an inelastic or even rigid connection between the anchor and the orthodontic appliances. The advantage to the indirect technique is that most orthodontists already design their movements of teeth based on traditional mechanics. Skeletal anchorage devices allow for more efficient movement of teeth and address a number of anchorage problem areas that previously were difficult or even impossible to resolve with traditional orthodontic mechanics alone. (35)

Fig. 1. Direct anchorage is achieved by adding a force from an elastic chain or thread to the loop in an existing orthodontic mechanical system to achieve retraction of the entire anterior segment of teeth. (Data from Nanda R. In: Nanda R, editor. Temporary anchorage devices in orthodontics. St Louis: Elsevier; 2008. p. 157.)
Fig. 2. An example of indirect anchorage using somewhat complicated palatal mechanics. The left first molar is tied with a ligature wire to a temporary anchor screw providing absolute anchorage. The right segment is planned to move distally, so an elastic chain is threaded from the hook behind the first bicuspid on the transpalatal bar. The final result is distalization of the entire right segment, a vector of force that is traditionally difficult or impossible to achieve with standard mechanics. (Data from Anka G. In: Nanda R, editor. Temporary anchorage devices in orthodontics. St Louis: Elsevier; 2008. p. 199.)

Success rates

The stability of mini-implants depends on mechanical factors such as device design and dimensions but also on biological factors such as bone quality, bone quantity and time before loading. (33, 44) Costello et al. reports considerably low failure rates below 5%. (35) In the latest systematic review of Schätzle, on comparing miniplates, palatal implants and miniscrews with each other, none of them showed statistically significantly higher survival rates than the other due to the wide scattering within the groups. When miniplates and palatal implants representing torque-resisting TAD’s were grouped together, they showed a statistically significant 1.9-fold lower clinical failure rate than did miniscrews. (46)

It is important to recognize that most of the data published are reported by the individuals who placed and used the devices, and as such the definition of failure may vary. There is an inherent self-reporting bias with such literature. Plate systems offer a greater degree of three-dimensional stability, and a higher integration with the bone structure because of the multiple
screws used for fixation than a single miniscrew. Consequently, the authors tend to use bone plates more often than miniscrews for cases that require longer treatment times or greater forces. (35) Miniplate systems allow changes of the force vectors without the need for repositioning of the TAD. Not many prospective studies in the level 1 evidence category exist. (67) According to Rahimi et al. most studies have significant reporting bias, disparate patient populations, and data analysis flaws. (67) Hereafter the different kinds of studies, success rates and the possible significant factors for TAD failure are tabulated (Table 1). The success rates for OBA’s range from 91.4% to 100% while for miniscrews they range between 37%-97%. (41, 44, 47, 52, 59)

Table 1:

<table>
<thead>
<tr>
<th>Authors</th>
<th>Kind of study</th>
<th>Type of TAD / length and diameter of fixation screws in mm</th>
<th>Manufacturer</th>
<th>N° of TADs/ Patient</th>
<th>Mean age in years / range</th>
<th>Success rate</th>
<th>Significant factors in TAD failure</th>
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<tr>
<td>Myawaki et al. (2003)</td>
<td>retrospective</td>
<td>2 types: mini screws and miniplates L = 5 D = 2.0</td>
<td>Not specified</td>
<td>151 / 51</td>
<td>21.8</td>
<td>96.4 %</td>
<td>High mandibular plane, inflammation</td>
</tr>
<tr>
<td>Cheng et al. (2004)</td>
<td>prospective</td>
<td>2 types of TADS: miniscrews, miniplates L-shaped L = 5 or 7 D = 2.0</td>
<td>Mondeal®, or Leibinger ®, Germany</td>
<td>140 / 44</td>
<td>29 (13 - 55)</td>
<td>Cumulative 89.0 %</td>
<td>Not specified</td>
</tr>
<tr>
<td>Erverdi et al. (2004)</td>
<td>Preliminary study</td>
<td>I-shaped L= 7</td>
<td>Leibinger ®, Germany,</td>
<td>20 / 10</td>
<td>(17-23)</td>
<td>100 %</td>
<td>/</td>
</tr>
<tr>
<td>Mommaerts et al. (2005)</td>
<td>Prospective registry</td>
<td>3 hole rectangular or triangular L = 5 or 7 D = 2.3</td>
<td>Surgi-Tec, Belgium</td>
<td>35 / 18</td>
<td>21</td>
<td>91.4</td>
<td>/</td>
</tr>
<tr>
<td>Choi et al. (2005)</td>
<td>retrospective</td>
<td>2 shapes: L-shaped T-shaped L = 5 D = 2.0 self-tapping</td>
<td>Martin, Germany</td>
<td>68 / 17</td>
<td>21.2 / (16.7 - 30.1)</td>
<td>92.7 % 92.6 %</td>
<td>Infection</td>
</tr>
<tr>
<td>Study</td>
<td>Type</td>
<td>Screw Type</td>
<td>Manufacturer/Model</td>
<td>Sample Size</td>
<td>Success Rate (Range)</td>
<td>Failure Reports</td>
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<tr>
<td>Londa et al. (2005)</td>
<td>Clinical</td>
<td>Straight 5-hole microplate</td>
<td>Medicon Corp., Germany</td>
<td>11/9</td>
<td>(14 – 34)</td>
<td>100 %</td>
<td></td>
</tr>
<tr>
<td>Ari-Demirkaya et al. (2005)</td>
<td>Prospective</td>
<td>Not reported</td>
<td>Not reported</td>
<td>32 / 16</td>
<td>Not reported</td>
<td>100 % (no failure reported)</td>
<td></td>
</tr>
<tr>
<td>Yao et al. (2005)</td>
<td>Retrospective</td>
<td>L- or Y-shaped</td>
<td>Mondeal® or Leibinger®, Germany</td>
<td>18 / 22</td>
<td>Not reported</td>
<td>100 % (no failure reported)</td>
<td></td>
</tr>
<tr>
<td>Kuroda et al. (2007)</td>
<td>Retrospective</td>
<td>3 types</td>
<td>Dentsply-Sankin, Tokyo, Japan</td>
<td>154/75</td>
<td>21.8</td>
<td>86.8 %</td>
<td></td>
</tr>
<tr>
<td>Chen et al. (2007)</td>
<td>Retrospective</td>
<td>L-shaped</td>
<td>Leibinger®, Germany</td>
<td>44 / 24</td>
<td>27.5 (18-35)</td>
<td>95.5 %</td>
<td></td>
</tr>
<tr>
<td>Erverdi et al. (2007)</td>
<td>Retrospective</td>
<td>L-shaped</td>
<td>Tasarim Med, Turkey</td>
<td>22 / 11</td>
<td>19.5</td>
<td>not reported</td>
<td></td>
</tr>
<tr>
<td>Chen et al. (2007)</td>
<td>Retrospective</td>
<td>3 types of TADS: microscrews</td>
<td>Mondeal® or Leibinger®, Germany</td>
<td>154/75</td>
<td>24.5 (12 - 55)</td>
<td>98.8 %</td>
<td></td>
</tr>
<tr>
<td>Cornelis et al. (2008)</td>
<td>Prospective</td>
<td>Straight 2- or 3-hole miniplates</td>
<td>Surgi-Tec, Belgium or KLS Martin, Germany</td>
<td>200 / 97</td>
<td>23.7 (9.8-48.1)</td>
<td>92.5 %</td>
<td></td>
</tr>
<tr>
<td>Chen et al. (2008)</td>
<td>Retrospective</td>
<td>3 types of TADS: microscrews</td>
<td>Mondeal® or Leibinger®, Germany</td>
<td>492 / 194</td>
<td>25.1 (11-57)</td>
<td>95.3 %</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- **Intrusion ; molar area**
- **Age; mandibular arch**
- **Bone density; inflammation; Pog-Nv; loading within 3 weeks after insertion**
A prospective study of an orthodontic bone anchor

Valerie Nols

The clinical studies examined many different variables possibly related to the success or failure of an OBA. Not many variables and correlations between the different variables were carried out using multivariate logistic regression analyses in relation with success and complications. The statistically significant factors for miniplate failure were: inflammation, posterior mandible, non keratinized mucosa, age, molar area, mandibular arch, bone density, loading within 3 weeks after insertion and bone thickness (table 1). (41-45, 68, 69) All possible risk factors that were deducted from the selected articles will be elaborated hereafter.

### Risk factors

<table>
<thead>
<tr>
<th>Study</th>
<th>Study type</th>
<th>Sample size</th>
<th>Plate type</th>
<th>Complications</th>
<th>Success (%)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schätzle et al. (2009)</td>
<td>Systematic review</td>
<td>586 / 406</td>
<td>L-shape locking plate L = 4 or 6 D = 2.0 selfdrilling screws</td>
<td></td>
<td>92.7 %</td>
<td></td>
</tr>
<tr>
<td>Hibi et al. (2010)</td>
<td>retrospective</td>
<td>61 / 32</td>
<td>(Compact lock 2.0; Synthes Maxillofacial, Paoli)</td>
<td>21.0 (11.4 - 35.1)</td>
<td>93.4 %</td>
<td>Bone thickness (threshold 1.1 - 1.4mm)</td>
</tr>
<tr>
<td>Eroglü et al. (2010)</td>
<td>prospective</td>
<td>74 / 37</td>
<td>L = 5 or 7 D = 2.0 Not specified</td>
<td>16 (12.2 – 21.7)</td>
<td>98.6 %</td>
<td></td>
</tr>
<tr>
<td>Takaki et al. (2010)</td>
<td>retrospective</td>
<td>904 / 455</td>
<td>3 types of TADs Miniscrews, palatal implants, miniplates (Y-plate and T-plate)</td>
<td>25.7 (8 - 68)</td>
<td>94 %</td>
<td></td>
</tr>
<tr>
<td>This study</td>
<td>prospective</td>
<td>106/61</td>
<td>3 hole rectangular or triangular L = 5 or 7 D = 2.3</td>
<td>21.8 (11.3 – 46.3)</td>
<td>93.3 %</td>
<td>Young age (&lt; 16yrs), anterior mandible</td>
</tr>
</tbody>
</table>
**Orthodontic bone anchor:**

*Length and diameter of the fixation screws*

The length of the fixation screws described in the literature varies between 4 mm and 10 mm. The most common lengths used for fixation of miniplates are 5 mm and 7 mm. In a review article of Janssen et al. lengths between 4 to 7 mm are considered as safe in most anatomical sites. There are no articles reporting a significant correlation between the length of the screws and a higher failure rate of miniplates. Hibi et al. stated that length is not a critical factor for stability because the extent to which the screw threads engaged depended substantially on bone thickness itself despite longer screws. The literature on miniscrews can provide more information while they are used as fixation screws for bone plates. The results need to be interpreted with caution because coupling 2 miniscrews in the line of force with a plate drastically minimizes the miniscrew failure rate from 17.8% to 6.2%, according to Wilmes et al. Another study mentioned that the success rate of miniplates with 2 miniscrews were approximately 10% higher than free standing mini screws although statistically not significant. One retrospective research describes a significant lower success rate in screws of 6 mm in comparison with screws of 8 mm. A recent study of Wilmes and Drescher found that 10 mm screws didn’t perform any better than 8 mm screws. Many other studies couldn’t find a significant correlation between the length of miniscrews and their success rate.

The diameter of the screws used for bone plate fixation in the literature varies between 1.5 mm and 2.3 mm. Miyawaki et al. demonstrated that miniscrews with a diameter of 1.0 mm showed a significant lower success rate (0%) than those with a diameter of 1.5 mm (83.9%) and 2.3 mm (85.0%). In one systematic review the diameter was studied using a meta-analysis. The miniscrews were divided into 3 groups. Screws with diameters of 2 mm and more showed a significant 1.8 times smaller failure risk than those with a diameter of 1.2 mm or less.
Self-tapping or self-drilling fixation screws

Self-drilling screws have a sharp and tapered apex to allow for placement without a predrilled pilot hole. Pre-drilling screws requires the placement of a pilot hole before implant insertion because the apex is not sharp enough to perforate the bony layer or because the implant is too small in diameter to allow placement into bone without the possibility of fracture. Self tapping refers to the ability of a screw to advance when turned while creating its own thread. Self drilling screws and pre-drilling screws can both be self tapping.

Authors don’t agree whether self-drilling or pre-drilling screws are more stable. Kim et al. suggested that self-drilling screws have better bone-to-implant contact than pre-drilling screws resulting in a higher initial stability. (72) Moreover there should be less contamination because pilot hole drilling is not required. (64) Türköz et al. also reported a higher success rate of self-drilling screws. (73) However according to Chen et al. self-drilling screws showed a higher failure risk than pre-drilling screws. (45) Recently Wilmes and Drescher advised that pre-drilling is required in all regions of high bone densities. Which comprises the whole mandible, the median parts of the alveolar ridge and the palate. To achieve sufficient insertion torques and to avoid excessive bone stresses, an optimal combination of pre-drilling diameter and implant must be chosen depending on insertion region and bone quality. As a clinical recommendation it is advisable to choose a drill with implant diameter minus 0.5 mm. (71) In several studies no statistical significant correlation was found between the type of screw and failure. (41, 53, 56, 57, 59)

Shape of the bone plate

Different shapes and sizes of the miniplates are described in the literature: L-shaped, T-shaped, Y-shaped, I-shaped rectangular or triangular comprising 2, 3 or 5 holes for screw fixation. (41, 68, 69, 74-78) Some articles studied the influence of the shape of the bone plate but didn’t seem to be a significant factor for success. (68)
**Surgical intervention**

The application of OBA’s requires 2 minor surgical interventions for placement and removal. Preoperative planning requires a careful clinical examination, at least a panoramic radiograph and clear communication between the treating orthodontist and the surgeon regarding positioning, activation and removal. The device should be placed in a location that is helpful for the orthodontic mechanics required by the orthodontist. Placement of the anchor is usually carried out under local anaesthesia. An incision (hockey-stick type; straight; L-shaped) is made and a mucoperiosteal flap is elevated. The selected OBA is contoured to fit the bony surface and the connection bar curved into a bayonet shape. Then pilot holes are drilled and the fixation screws are inserted to firmly attach the base plate to the bony surface. The location of emergence of the connection bar should be at the mucogingival junction or within the attached gingiva. The wound is then closed and sutured. Brushing instructions for the transmucosal part of the OBA should be given to the patient as well as an antiseptic gel or mouthrinse to prevent and control infections. Finally a cold pack can be provided for postoperative comfort.

The surgical procedure was considered very to moderately easy by the surgeons. The time required to insert an OBA is approximately between 15 and 30 minutes. As with all surgical interventions, there is a learning curve. Familiarity of the surgeon with the OBA and it’s placement techniques may be a key factor determining it’s success rate. The removal surgery appeared both easier and less time consuming than the placement procedure. Placement and removal procedures seemed to be associated with minimal post-operative pain and inconvenience. The principal adverse effect is swelling persisting on average for 5 days following surgery. Cheek irritation was another frequently reported problem. To place miniplates in the context of other dental procedures it would seem that they are always perceived as better than headgear, nearly always better than braces, better or equivalent to extractions and about equal or worse than cavity restorations.

Operator-related complications can occur for a variety of reasons. Small screw systems require very careful placement, and a fine tactile sense is necessary to avoid stripping the bone screw interface during placement. Overworking the screw material can also lead to fracture. Poor stability can occur because of poor choice of placement location.
Fig. 3: (A–C) Maxillary anchor plate procedure. A small L-shaped incision is used at the mucogingival junction to allow for placement of an anchor plate. Three screws or more are placed with appropriate positioning for the indicated orthodontic mechanics. Closure is achieved with resorbable suture. (Source: Oral Maxillofacial Surg Clin N Am 22 (2010) 91–105 doi:10.1016/j.coms.2009.10.011. Costello et al. Skeletal anchorage devices for orthodontics)

**Patient**

**Gender**

A higher mean bone density value of the implant sites is more present in males than females, this finding may be related to the hormonal peculiarities in females and generally higher bone mass in males. An earlier study including the measurement of the bone mineral contents in the jaws and forearms have disclosed lower bone mineral densities in females in comparison with males and larger bone mineral content loss in elderly females throughout adult life.(80) In most studies the patient samples showed a higher incidence of female patients.(19, 39, 41, 42, 47, 69, 77, 81, 82) A correlation between gender of the patient and success rate of OBA’s is mentioned in some studies but wasn’t statistically significant.(68, 69)
Age

The literature doesn’t agree on whether young age influences the failure rate of TAD’s. Most studies reported the factor age not to be a significant variable. (41-44, 47, 63) Cornelis et al. mentioned a higher failure rate due to mobility in growing patients than in adults. (78) Although their surgeons were always instructed to place the attachment arm penetrating the tissue at the muco-gingival junction, this might be more difficult in younger patients, when alveolar height tends to be shallow, width of attached gingiva is less, and access is restricted. Another study confirmed that TAD’s placed in young patients were at a significantly greater risk of failure due to less bone density and thickness of the cortical bone. (41, 42) When analyzing the literature, the question that applies to all types of skeletal anchorage is the point of insertion with adequate bone potential, a factor of particular relevance in the cortical area. (83-85) The best approach for ensuring biomechanical strength is actual contact with mature lamellar bone. (84, 86) The literature on miniscrews describes that the density of cortical and cancellous bone in adolescents is less than in adults and mini-implant failure during orthodontic treatment is therefore more often observed. (87) In young patients the level of bone maturity is low and a higher bone metabolism exists. (52)

Oral Hygiene

Positioning of anchorage elements outside the dental arch fairly often leads to discomfort and more difficult care. (88) Mild infection can be controlled by antiseptic mouthwash and careful brushing techniques. In general the literature insists on the extreme importance of oral hygiene. Because oral inflammation is one of the contributing factors to failure of TAD’s, it is important to motivate patients with TAD’s to maintain optimum oral hygiene. (41, 53) A single tufted brush to clean the TAD is a useful aid. (89) Sato et al. suggested that the environment in crevices around titanium orthodontic anchor plates is anaerobic and supports anaerobic growth of bacteria, which may trigger inflammation in the tissues around the plates. Therefore, orthodontic treatment with titanium anchor plates requires strict oral hygiene and regular professional plaque control in order to prevent infection. (90) Mouth rinses are recommended in presence of inflammation. (74, 91)
**Other patient related risk factors:**

Although TAD’s may be placed under local anesthesia and require minimal surgery, good general health is an important consideration for uneventful healing and avoidance of inflammation around the implant.(61)

- **Tobacco smoking:** Patients who smoke more than 10 cigarettes a day are considered to be heavy smokers and have poor wound healing.(92) There is an increased risk of peri-implantitis in smokers compared with nonsmokers (reported odds ratios from 3.6 to 4.6). The combination of a history of treated periodontitis and smoking increases the risk of implant failure and peri-implant bone loss.(93) Since orthodontists have regular contact with teenagers, one author suggests that orthodontists play an important role in discouraging youngsters from smoking.(94)

- **Diabetes:** Oral complications include xerostomia, burning mouth and/or tongue, candidal infection, altered taste, progressive periodontal disease, dental caries, acetone breath, oral neuropathies, parotid enlargement, sialosis and delayed wound healing. These complications can occur even when the blood glucose is well controlled due to impaired neutrophil function but are all more severe in uncontrolled diabetes mellitus (DM). (95) Placement of Tad’s and orthodontic treatment should be avoided in patients with poorly controlled insulin-dependent DM as these individuals are particularly susceptible to periodontal breakdown and have poor wound healing.(96) Even in well-controlled diabetics good oral hygiene is essential. These patients are more prone to gingival inflammation and periodontal breakdown which can cause an implant to fail.(95)

- **Risk of infective endocarditis:** Since placement of TAD’s causes an insult to the oral mucosa and underlying bone, a prophylactic antibiotic has been recommended for patients who are at risk of infective endocarditis.(97)

- **Medication:** Any medication likely to hinder wound healing, gingival health and tooth movement should be taken into account prior to placement of a TAD. Examples of medication that may lead to failure of a TAD are: bisphosphonates, immunomodulators, anti-epileptics, inti-aggregation medication and anticoagulants.(95)
Location

Maxilla/mandible

The cortical bone in the upper jaw has a very low thickness of 0.4-1.6 mm. It is less retentive than that of the mandible because it is thinner and the maxillary bone structures are very delicate for osseo-integrated anchorage.(88) Therefore it could be assumed that the success rate in the mandible would be higher. Chen et al. confirmed this hypothesis, describing a higher failure rate in the maxilla than in the mandible.(91) Several studies contradicted the hypothesis by describing a higher failure rate in the mandible.(41, 42, 47, 68, 78) The low success rate in the mandible might be due to surgical mediated stress such as overheating of the bone due to drilling when harder bone is encountered causing resorption of the cortex.(47, 63) The external cortical bone in the anterior lower jaw is thicker, particularly at the external oblique line and in the symphysis area, which has a thickness of up to 3 mm.(98, 99) According to Tsunori et al. the mandibular cortical bone thickness ranges from 1.1 mm to 3.7 mm depending on the location in the mandible.(100) Even with irrigation during drilling there is greater chance of generating heat above 47°C which is the critical temperature for causing bone damage and concomitant bone resorption.(101-103) Türköz et al. recommended both internal and external cooling with saline irrigation.(73) Another plausible reason for a higher failure rate in the lower jaw, reported by several authors, is the low level of attached gingiva.(43, 63, 76) There is also a possibility that bone healing was inhibited due to occlusal and/or masticatory pressure on the connection arm exposed in the oral cavity.(47) Mommaerts et al. suggested to prevent patients from chewing on the OBA. To place it after an initial phase of orthodontic alignment and so the fixed appliance prevents, to a certain extent, excessive contact with the OBA.(36). Miniscrews showed similar results with some articles describing significantly higher success- and survival rates in the upper jaw.(53, 55) Other authors are slightly nuanced, expressing a greater risk on failure in the mandible.(41, 42) Most studies on miniscrews didn’t show any correlation between the jaw and the success rate. (44, 45, 56, 57)
**Anatomic location**

A very small part of the selected articles studied the correlation between the anatomical location of the OBA and the success rate. Cheng et al. stated that TAD’s in the posterior mandible were more prone to failure mainly due to the shallow buccal vestibule with little attached gingiva, poor oral hygiene and/or the surgical placement difficulty of the anatomical location. (41) Choi et al. reported a low success rate in the mandibular body region. (68) This finding was confirmed by Takaki et al., describing a higher success rate in the zygomatic buttress region (98%) than the mandibular body region (85%). (47) Motoyoshi et al didn’t find a significance between placement location and success. (104) Other authors didn’t mention a statistical correlation between the anatomical position and a higher failure rate. (39, 42, 46, 91)

**Keratinized/non-keratinized gingiva**

A higher failure rate in the lower jaw, reported by several authors, is because of the low level of attached gingiva. (43, 63, 76) The location of the miniplate’s point of exposure to the oral cavity is absolutely critical. It is important to limit mucous membrane movement close to the bone anchor. A key factor for good soft tissue management is placing the OBA with the connecting bar penetrating the mucosa at the muco-gingival junction or in the attached gingiva. (39, 105) Locating the horizontal component of the incision at the muco-gingival junction or 1 mm within the attached gingiva appears to be important. (39) Non-keratinized emergence sites enhance mechanical soft tissue irritation which contributes to the occurrence of infection, hypertrophy and plate mobility. (41, 68, 79) It is well known that inflammation of the peri-implant tissue causes peri-implant bone loss, which can lead to implant mobility. (105-107) Takaki et al. described in their clinical study of temporary anchorage devices that inflammation of the peri-implant tissues occurred at a significantly higher rate in plate-type than in screw-type anchorage devices and that inflammation frequencies depended on the degree of mucosal penetration. (47) Sugawara and Nishimura reported that infection occurs in about 10% of patients. (68, 108)
Bone quality – density and thickness

Miniscrews do not osseointegrate while their anchorage stability results from mechanical interlock. (25, 29-31) Thus, their anchorage potential is most likely influenced by the quality and quantity of bone into which they are placed. (109)

Bone quality at the implantation site is one of the most important factors profoundly influencing implant failure rates. The characteristics of the bone are dependent on bone micro-architecture. According to Lekholm and Zarb (1985), bone quality has been classified in four categories based on its radiographic appearance and the resistance at drilling: type 1 bone: in which almost the entire jaw is composed of homogenous compact bone; type 2 bone: in which a thick layer of compact bone surrounds a core of dense trabecular bone; type 3 bone: in which a thin layer of cortical bone surrounds a core of dense trabecular bone of favourable strength; type 4 bone: in which a thin layer of cortical bone surrounds a core of low-density trabecular bone of poor strength. (110) The presence of dense bone may favour early implant stabilization.

Poor bone quality seems to cause a higher failure rate. (45) Motoyoshi et al. found that the success rates in the groups with cortical bone thickness (CBT) ≥ 1.0 mm were significantly higher than those in the groups with CBT < 1.0 mm. This concurs with the finding of Motoyoshi et al. verifying 1 mm as the clinical threshold for CBT. (111) Other authors also mention bone thickness/density to be a critical factor in supporting the screws. (45, 69) A correlation exists between bone quality, according to the Lekholm & Zarb classification, and Hu (Hounsfield units) computerized tomography values. The primary implant stability measured with resonance frequency analysis depends on bone density values, bone quality and implant location. (112)

Several authors recommend implant type selection and implant site preparation modalities based on the local bone quality. Despite the fact that primary stability is assumed to be a crucial factor for the successful use of orthodontic mini-implants, there is currently a lack of knowledge about factors having an impact on this parameter. A valid method to assess the primary stability of implants quantitatively is the measurement of insertion torques. (26, 104, 113) In the study of Wilmes and Dreschen the results clearly showed that bone quality
(compacta thickness) and the preparation of the implantation site have a great impact on insertion torques, and therefore on primary stability.\(^{(71)}\)

The process leading to mini-implant failure begins with bone resorption occurring from a superior to an inferior position in cancellous bone, resulting in the loss of cancellous bone support. Consequently, bone resorption occurs at the superior and inferior margins of the cortical bone. Eventually, the mini-implant can no longer resist the orthodontic force, and it loosens.\(^{(104)}\)

**Orthodontic application**

**Time of loading**

In general the time of loading can be subdivided into 2 groups: immediate loading or delayed loading. Immediate loading is generally defined as loading at time of placement of the TAD. Some authors use the term ‘early loading’ to nuance the fact that the OBA isn’t immediately loaded at time of placement but within a few days or weeks mostly to allow initial wound healing.\(^{(45, 114, 115)}\) Delayed loading can be defined as anything but immediate loading. On the other hand, in some studies it is used to define waiting periods before orthodontic loading of \(\geq 6\) weeks. The recent literature reports relatively short healing periods ranging from 6 weeks to immediate loading.\(^{(25, 26, 88, 116)}\) De Clerck et al. indicated a healing period of 2-4 weeks before orthodontic loading to allow the soft tissues to heal.\(^{(115)}\) Chen et al. concluded from their study that duration of healing is a significant factor for success of a TAD. Avoidance of loading until after 3 weeks of healing when primary stability of the TAD is being established cannot be overemphasized even though osseointegration is not required.\(^{(45)}\) However these results are in contrast with the outcomes of other studies.\(^{(42, 44, 57, 59)}\)

The timing of loading was not related to the success rate according to Kuroda et al.\(^{(43)}\) Moreover Miyawaki et al. claimed that the number of days from implantation to force application was not associated with stability and that immediate loading of a screw-type implant anchor is possible if the applied force is less than 2 N.\(^{(44)}\) Miniscrews do not osseointegrate while their anchorage stability results from mechanical interlock which eliminates the need for a waiting period before force application and permits easy removal.\(^{(25, 29-31)}\) While in the literature there didn’t seem to be a consensus about the
appropriate time of loading. It wasn’t clear whether immediate loading generated more OBA failures than delayed loading. Therefore it became the main question for this masterthesis.

**Force magnitude**

The literature on OBA’s didn’t elaborate the subject of force magnitude much. One recent article compared 2 different force magnitudes of 150 g and 450 g but didn’t find a correlation with success.\(^{(79)}\) Several other authors didn’t find a correlation between the force magnitude and the success rate.\(^{(41, 59)}\) In general the applied force magnitudes ranges between 100-200 g.\(^{(42, 69, 75-77, 91, 114, 117)}\) De Clerck et al. uses a lower force of 100 g. for the first few months to increase it up to a maximum of 200 g.\(^{(114)}\) For force application, rubber elastics, coil springs or push coils are used.

**Orthodontic indications**

The different uses of miniplates in orthodontic and orthopedic management of malocclusions with respect to the spatial planes of movement, namely, sagittal and vertical.

**Sagittal plane:**

- Retraction of anterior teeth:
  De Clerck et al. describes sliding mechanics with power arms on the wire in combination with a sliding coil and a loading force of 50g – 150g. The mean rate of distalization was 1.14 mm per month\(^{(115)}\). Retraction of anterior teeth can be achieved with or without extractions.\(^{(17, 118)}\)

- Retraction of whole dentition or distalization of molars:
  The first case report of molar distalization was published in 1985 by Jenner and Fitzpatrick.\(^{(27)}\) A bone plate was inserted into the ramus and direct traction was applied to distalize a lower first molar by 3.5 mm in 5 months. Sugawara et al. published several studies on distalization of molars in the mandible and maxilla reporting a mean distalization of the mandibular molars of 3.5 mm at crown level and 1.8 mm at root level.\(^{(19, 82)}\) The maxillary molars were distalized with a mean amount of 3.78 mm at crown level and 3.20 mm at root level.\(^{(19)}\)
Protraction of molars or the whole dentition:
Moving posterior teeth in the mesial direction is difficult because of lack of anchorage from the anterior segment. (119) In case of agenesis of a permanent bicuspid the orthodontist may choose to close the space by moving the posterior teeth to the mesial. (35) This can also be the case when lateral incisors are missing. The whole dentition is then moved to the mesial. In the maxilla the ideal position for the OBA in case of mesial movement of the teeth are at the piriform aperture or between the canine and the first premolar. In the lower they are placed jaw between the canine and the first premolar. (75)

**Vertical plane:**
- Intrusion or extrusion:
  Intrusion of one tooth or a whole segment is always difficult to achieve without the side effect of extrusion of the anchorage teeth. For the correction of an open bite intrusion of posterior teeth is essential. Many authors reported on the intrusion of maxillary or mandibular molars while also achieving a counter clockwise mandibular rotation. (28, 74, 120-122) Erverdi et al found that it was possible to acquire an open-bite correction of 5.1 mm in 9.6 months with this technique through 3° of mandibular autoclosure. (18) The study conducted by Seres et al. confirmed these results. (123) Correcting the overeruption of unopposed teeth prior to prosthodontic replacement of missing teeth is mostly described in the literature using miniscrews. Intrusion of a single overerupted tooth, because of an edentulous space in the opposite arch, can be remedied with miniplates. (28, 124, 125)
- Uprighting molars:
  One of the more difficult movements in orthodontics is uprighting a molar tooth that has moved mesialy into an edentulous space. Without a TAD it may be very difficult to upright the tooth without the undesirable side effects of extrusion and reciprocal forces exerting on the anchorage unit. (66)

**Orthopedics:**
The use of implants for orthopedic purposes was first reported in 1999 by Henry et al. (126) By placing implants in the zygomatic buttress of the maxilla with traction forces towards a
facemask. The maxilla was advanced anteriorly and inferiorly by 4 mm. In the context of facemask therapy, the objective is to augment growth at the sutural sides by adding additional force to the natural force, separating the sutures more than would otherwise occur. The usual effects of conventional facemask therapy on the dentition include extrusion and mesial movement of the maxillary molars, proclination of the maxillary incisors, and retroclination of the mandibular incisors.(127) Kircelli et al. studied the orthopedic effect of miniplates placed on the lateral nasal wall of the maxilla in conjunction with facemask therapy in the late mixed-dentition period. (128) They found a remarkable advancement in the middle face and consequent fullness in the soft-tissue profile can be achieved by using skeletal anchorage in conjunction with facemask therapy in the late mixed-dentition period. De Clerck et al. didn’t use a facemask but treated Class 3 patients exclusively by intermaxillary traction between miniplates placed in the maxilla and in the mandible, in combination with a bite plane to jump the anterior crossbite. (21, 114) The soft tissue profiles considerably improved, with anterior displacement of the whole midface (infraorbital ridge, nose, and upper lip), reducing the paranasal concavity. The comparison of the cephalometric data from the experimental group with the untreated control group showed highly significant maxillary advancement (approximately 4 mm). This effect was not limited to the alveolar bone but extended up to the levels of the pterygomaxillary fissure and the orbital ridge as well. (21)

Fig. 3: Class 3 correction achieved with the bone-anchored maxillary protraction (BAMP) orthopedic protocol. (source: Angle Orthodontist, Vol 80, No 5, 2010 author: Cevidanes L. Comparison of two protocols for maxillary protraction: bone anchors versus face mask with rapid maxillary expansion)
Aim

In the literature there didn’t seem to be a consensus about the appropriate time of loading. It wasn’t clear whether immediate loading generated more OBA failures than delayed loading. Therefore it became the main question for this masterthesis. Does immediate loading of Orthodontic Bone Anchors (OBA) generate more failures than delayed loading? The other aim was to evaluate the impact of different prospectively determined parameters: gender, age (young age group< 16 yrs vs. mature age group≥ 16 yrs), time of loading (delayed vs. immediate), jaw, location, fixation screw length, complications and orthodontic indications on the success rate of the use of OBA’s as temporary anchorage devices in orthodontic treatment.

The following part of the thesis is based on the manuscript submitted for revision on April 4th 2011 in The International Journal of Oral & Maxillofacial Implants. Manuscript title: A long term prospective study of an orthodontic bone achor.
Abstract

Title: A long term prospective study of an Orthodontic Bone Anchor.

Aim:

The main question was whether immediate loading of Orthodontic Bone Anchors (OBA) generates more failures than delayed loading. The other aim was to evaluate the impact of different variables on the success rate of the use of OBA’s as temporary anchorage devices in orthodontic treatment.

Material and Methods:

In a prospective registry 61 consecutive patients (37 ♀, 24 ♂) were treated orthodontically in combination with skeletal anchorage. In total 106 OBA’s were placed by one experienced maxillo-facial surgeon over a period of 5 years (2001-2006). An independent evaluator compared and analyzed different prospectively determined parameters: gender, age (young age group< 16 yrs vs. mature age group≥ 16 yrs), time of loading (delayed vs. immediate), jaw, location, fixation screw length, complications and orthodontic indications.

Definition of success: Capacity of maintaining the function of anchorage throughout the orthodontic treatment. Premature removal of an OBA due to infection, serious mobility or persisting pain was considered as a failure.

Statistical analyses: Fisher’s exact tests for analysis of associations between the categorical variables. Success and complications were evaluated using multivariate logistic regression (significance level p= 0.05).

Results:

The reported success rate in this study was 93.3%. In total 7 (6.7 %) OBA’s were removed prematurely. Time of loading didn’t influence the failure rate. A statistically higher failure rate was noted in the mandible (p= 0.024). Anteriorly positioned OBA’s exhibited a
significantly higher failure rate \((p= 0.034)\) than OBA’s positioned posteriorly. The young age
group presented more failures \((p= 0.02)\) than the mature age group.

**Conclusion:**

According to the results of this study OBA’s are a reliable treatment modality to obtain
absolute orthodontic anchorage. Immediately loaded OBA’s don’t generate more failures
than delayed loaded OBA’s. Age, jaw and position seem to play an important role in the
success of OBA’s.

**Key words:** orthodontic anchorage, orthodontic bone anchor, immediate loading, delayed
loading, prospective study.
IV. Introduction

Orthodontic anchorage is an important factor in obtaining stable treatment results in orthodontics. Therefore skeletal anchorage is a field that has known a strong development in orthodontics over the last 15 years although it has been studied for more than 60 years.(5-7) Since the introduction of implants for orthodontic anchorage, different types of implant devices and application mechanics have been explored.(5) Orthodontic Bone Anchors (OBA’s) derive from the small titanium osteosynthesis plates used in cranio-maxillo-facial surgery for fracture repair or segment fixation in orthognathic surgery, firstly introduced by Michelet et al. in 1973.(34) Jenner and Fitzpatrick used these “miniplates” already in 1985 for orthodontic anchorage.(27) The interest for this plate-type implant concept started after a number of innovations in design, mainly with the addition of common orthodontic tools.(35, 36) OBA’s can be placed anywhere on the buccal bony surface, provided the cortex has a minimum thickness to hold the screws such as the symphysis, the posterior body and the ramus of the mandible, the zygomaticomaxillary buttress or the piriform buttress.(37)

Currently, the literature doesn’t provide many long-term prospective studies with a large patient sample evaluating a series of different variables in relation to the success of OBA’s.(41, 75, 78) This long term prospective registry examined a large sample to determine whether immediate loading of the OBA results in more failures than delayed loading. Another aim was to evaluate the impact of different variables on the success rate of OBA’s as temporary anchorage devices (TAD) in orthodontic treatment.
V. **Material and methods**

A total of 61 consecutive patients (24 male and 37 female) with ages ranging from 11.3 years to 46.3 years (mean age 20 yrs, S.D. 11.3) requiring skeletal anchorage for orthodontic purposes were included in this prospective registry. In this study, 106 OBA’s of one brand (Surgi-Tec NV, Sint-Denijs-Westrem, Belgium) were placed by a single experienced maxillo-facial surgeon (M.Y.M.) over a time span of 5 years (2001-2006). An independent evaluator (V.N.) compared and analyzed the different parameters which were determined prior to the start of the observation period (prospective case series study).

The titanium OBA consists of a sand-blasted and acid-etched base-plate (0.6 mm thick) that is rectangular or triangular used for bony fixation stabilized with self-tapping monocortical screws (diameter 2.3 mm, length 5, 7 or 10 mm). The machine polished flat connection bar, which is wider than it is thick, is projected through the mucosa into the oral cavity. The connection bar is short in variants used in the retromolar area and extra long in the tree-stem-shaped variants that allow tooth migration along the OBA. The coronal part has a hook for orthodontic force application such as Ni-Ti coil springs or rubber elastics. There are also types provided with a bracket-like slot or a tube (Fig. 4, 5).

![Figure 4: Orthodontic Bone Anchor (OBA) with hook as orthodontic force application tool. The base-plate is 0.5 mm thick, sandblasted and acid-etched. (Source: 3-D images OBA of Prof. Dr. Mommaerts in cooperation with Surgi-Tec)](image-url)
Figure 5: Orthodontic Bone Anchor (OBA) with tube (left) or bracket (right) as orthodontic force application tool. (Source: 3-D images OBA of Prof. Dr. Mommaerts in cooperation with Surgi-Tec)

Placement of the anchor was carried out under local anaesthesia infiltration. A hockey-stick type incision was made with the horizontal leg preferably in attached gingiva and a mucoperiosteal flap was elevated. The anchor plate length was selected according to the distance between the implantation site and the dentition. Then the selected OBA was contoured to fit the bony surface and the connection bar curved into a bayonet shape. The latter to reduce the circumference of the portion piercing the gingiva and to facilitate cleaning of the posterior portion of the connection bar. Pilot holes were drilled and the self tapping monocortical fixation screws were inserted to firmly attach the base plate to the bony surface. The choice of a specific length was based on clinical estimation by the operator before installation The location of emergence of the connection bar should be at the mucogingival junction or within the attached gingiva. The wound was closed and sutured with absorbable suture (Vicryl Rapide 4-0, Ethicon, Neuilly, France). Brushing instructions for the transmucosal part of the OBA were given to the patient as well as an antiseptic gel (Corsodyl
gel 1% GSK Consumer Healthcare, Genval, Belgium) to prevent and control infections. A cold pack was provided for postoperative comfort. Except for mild facial swelling, postoperative discomfort was usually minimal.

The sample was divided into 2 groups: the immediate loading (IL) group with 52 OBA’s and the delayed loading (DL) group with 54 OBA’s. The choice for these 2 different loading times depended on the presence or absence of fixed appliances. The OBA was immediately loaded if the patient already had a fixed brace with a Ni-Ti coil spring or a rubber elastic (1N). In the DL group, a latency period of 2 months was respected before any orthodontic force was applied (Fig. 6).

Figure 6: Intraoral view of immediate loading after an initial phase of tooth alignment before and after closure of the diastema between the elements 3.4 and 3.6. (Source: inta-oral pictures of Prof. Dr. Mommaerts)

Different parameters were examined: demographic details (age, gender), location of placement (mandible, maxilla, anterior, posterior), time of force application (IL and DL), date of placement and removal of the OBA, orthodontic indication for placement of an OBA (closing and opening diastemas, proclination or retroclination of the dental arch, intrusion, uprighting of molars), screw length (5, 7 or 10mm), type of connection bar (short, medium, long), type of force application tool (hook, tube or bracket), reason for removal of the OBA (end of treatment, persisting severe inflammation or severe mobility of the bone anchor), and orthodontic result (Tables 2 and 3).
Table 2: Demographic details, OBA details, reasons for removal and orthodontic result.

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patients</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Mean age</td>
<td>20 yrs range 11.3-46.3</td>
<td></td>
</tr>
<tr>
<td>Female/Male</td>
<td>37 / 24</td>
<td>60.7/ 39.3</td>
</tr>
<tr>
<td>Young age group (&lt;16 yrs)</td>
<td>39</td>
<td>65.1</td>
</tr>
<tr>
<td>Mature age group (≥ 16 yrs)</td>
<td>22</td>
<td>34.9</td>
</tr>
<tr>
<td><strong>Orthodontic Bone Anchor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>Number of OBA/patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=1</td>
<td>23</td>
<td>37.7</td>
</tr>
<tr>
<td>n=2</td>
<td>32</td>
<td>52.5</td>
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<tr>
<td>n=3</td>
<td>3</td>
<td>4.9</td>
</tr>
<tr>
<td>n=4</td>
<td>3</td>
<td>4.9</td>
</tr>
<tr>
<td>Location (Mnd/Mx)</td>
<td>66 / 40</td>
<td>62.3 / 37.7</td>
</tr>
<tr>
<td>Position (Ant-Post)</td>
<td>82 / 24</td>
<td>77.4 / 22.6</td>
</tr>
<tr>
<td>Immediate loading</td>
<td>52</td>
<td>49.1</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------</td>
<td>-----</td>
</tr>
<tr>
<td><strong>Delayed loading</strong></td>
<td>54</td>
<td>50.9</td>
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<tr>
<td><strong>Connection bar</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(short/medium/long)</td>
<td>19 / 81 / 6</td>
<td></td>
</tr>
<tr>
<td><strong>Fixation screw length (mm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-5-5</td>
<td>30</td>
<td>28.3</td>
</tr>
<tr>
<td>7-7-7</td>
<td>14</td>
<td>13.2</td>
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<tr>
<td>7-7-5</td>
<td>35</td>
<td>33.0</td>
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<tr>
<td>5-5-7</td>
<td>15</td>
<td>14.2</td>
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<td>2 fixation screws</td>
<td>4</td>
<td>3.8</td>
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<tr>
<td>Other combinations</td>
<td>3</td>
<td>2.8</td>
</tr>
<tr>
<td>Missing data</td>
<td>5</td>
<td>4.7</td>
</tr>
<tr>
<td><strong>Force application tool</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(hook / bracket / tube)</td>
<td>57 / 26 / 23</td>
<td>53.8 / 24.5 / 21.7</td>
</tr>
<tr>
<td><strong>Reasons for removal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of orthodontic application</td>
<td>98</td>
<td>92.5</td>
</tr>
<tr>
<td>Infection</td>
<td>3</td>
<td>2.8</td>
</tr>
<tr>
<td>Mobility</td>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td>Condition</td>
<td>Number</td>
<td>%</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------</td>
<td>----</td>
</tr>
<tr>
<td>Mobility + infection</td>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Orthodontic result</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfactory</td>
<td>96</td>
<td>90.6</td>
</tr>
<tr>
<td>Compromise</td>
<td>8</td>
<td>7.5</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
<td>1.9</td>
</tr>
</tbody>
</table>
Table 3: Orthodontic indications for 106 OBA’s in relation to the orthodontic force application tools.

<table>
<thead>
<tr>
<th>Orthodontic indication</th>
<th>frequency</th>
<th>%</th>
<th>Hook</th>
<th>%</th>
<th>Bracket</th>
<th>%</th>
<th>Tube</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closing diastemas</td>
<td>68</td>
<td>64.2</td>
<td>48</td>
<td>70.6</td>
<td>13</td>
<td>19.1</td>
<td>7</td>
<td>10.3</td>
</tr>
<tr>
<td>Opening diastemas</td>
<td>5</td>
<td>5.7</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>40</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>Proclination of the dental arch</td>
<td>9</td>
<td>8.5</td>
<td>5</td>
<td>55.6</td>
<td>/</td>
<td>/</td>
<td>4</td>
<td>44.4</td>
</tr>
<tr>
<td>Retroclination of the dental arch</td>
<td>10</td>
<td>9.4</td>
<td>2</td>
<td>20</td>
<td>4</td>
<td>40</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Intrusion (bite opening)</td>
<td>10</td>
<td>6.6</td>
<td>2</td>
<td>28.6</td>
<td>3</td>
<td>42.8</td>
<td>2</td>
<td>28.6</td>
</tr>
<tr>
<td>Uprighting of molars</td>
<td>4</td>
<td>3.8</td>
<td>/</td>
<td>/</td>
<td>4</td>
<td>100</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Complex</td>
<td>2</td>
<td>1.9</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>

At time of removal of the bone anchor a clinical observation was carried out with emphasis on mobility of the plate and/or fixation screws, bony overgrowth on the plate and/or fixation screws, infection of surrounding tissues or bone, changes of the surrounding tissues such as gingival recession.
In case of missing data in the registry, as well as for the orthodontic result, the file of the patient in question was consulted and the treating orthodontist was contacted. All data of these prospectively determined parameters were tabulated.

Success of the OBA is defined as the capacity of maintaining the function of anchorage throughout the course of orthodontic treatment without persistent infection or severe mobility of the OBA. Persisting infection that did not subside after local cleaning and antibiotic treatment or when the OBA was unable to resist the orthodontic force due to significant mobility, resulting in the premature removal of the anchorage device, is considered as a failure.

Considering the statistical analyses, the patients were subdivided into 2 groups for better understanding of the failures. A young age group (< 16 yrs) including 39 patients and a mature age group (≥ 16 yrs) including 22 patients was defined according to growth potential.

Statistical analysis was performed using IBM SPSS v18. Fisher’s exact test was used for the analysis of associations between categorical variables. Success of the anchorage system was analyzed using binary logistic regression. The significance level was set at α= 0.05.
VI. Results

The number of successful OBA’s is 98 representing a success rate of 93.3%. Only 7 OBA’s (6.7%) out of 106 were removed prematurely. For one OBA data on success was unavailable. The apparent reasons for removal were persisting infection without mobility in 3 cases and persisting infection in combination with severe mobility of the anchorage device in 2 cases. There was no sign of infection in 2 cases, only increased mobility of the OBA. In one case there were missing data concerning the reason for removal of the OBA.

The failure rate of the OBA’s was statistically higher in the mandible (p= 0.024) although most failures were hypothetically expected to occur in the maxilla. The time of loading (immediate or delayed) didn’t influence the failure rate.

Logistic regression analyses showed a clear correlation between “success” and “jaw” (mandible) in relation to the location of the anchorage device. OBA’s positioned anteriorly had a significantly higher failure rate (p= 0.034) than those located posteriorly. Six out of 7 failed OBA’s were situated anteriorly. The only failed OBA in a posterior location was already mobile prior to orthodontic loading.

Age is also a significant variable revealing a correlation with success and the mandible. The young age group exhibited more failures with a significancy of p= 0.02. Six out of 7 failed OBA’s were placed in young patients (<16 yrs).

The clinical observations at time of removal of the bone anchor revealed mild to moderate infection of the surrounding tissues in 4 OBA’s of which only 3 had to be removed before the end of the orthodontic application. A combination of infection and plate mobility was detected in 6 OBA’s of which only 2 failed. Mobility of the anchor without infection was observed in 4 cases of which 2 had to be removed prematurely. Gingival recession uncovering 1 or 2 fixation screws was a rare clinical complication seen in 5 cases (4.8%). A remarkable phenomenon at time of removal was bone overgrowth in 10 cases (9.5%), covering the bone plate and/or fixation screws in the apical region, always in the mandible and only in the young age group. In 76 OBA’s or 72.4 % none of the previously stated clinical observations were detected (Table 2).
Considering the failure of the fixation screws, 5 loose screws were detected in the maxilla and 19 in the mandible. Screw failure was more often situated in the mandible of the young age group (p= 0.002). Loosening of all fixation screws occurred in 28.6% of all screw failures leading to the loss of 4 OBA’s. The coronal fixation screw showed more failures (43%) than the middle screw (21.4%) or the apical screw (not significant).

None of the other variables such as complications, time of loading, screw length or gender presented any statistical correlation, although a much higher failure rate in female patients was observed. No statistical correlation was found between orthodontic indication and complications nor between orthodontic indication and success. The main orthodontic indication in this study was closing diastemas (64.2%), followed by proclination, retroclination and intrusion (Table 3).

In 96 (90.6%) of 106 OBA’s the predetermined orthodontic tooth movement was achieved and a satisfying orthodontic result was reported. In 8 cases a compromise for the final orthodontic result had to be considered or (7.5%), of which 4 due to premature removal of the OBA. The orthodontic result remained unknown in 2 cases.
VII. Discussion

Anchorage control is fundamental for successful orthodontic treatment of malocclusions. The ideal absolute anchorage is total resistance to unwanted reciprocal tooth movements and independence from patient compliance. (129) Temporary anchorage devices (TAD’s) allow orthodontic movements that were previously thought to be difficult or even impossible. (17-19) A variety of problems encountered by the orthodontist on a regular basis such as missing permanent teeth, loss or absence of anchor teeth and non-compliance for extra-oral traction are now more efficiently treated with skeletal anchorage as an adjunct to traditional mechanics leading to a reduction in unwanted side effects. (75) In this study the orthodontists reported 90.6 % perfectly satisfying orthodontic results using OBA’s in a total of 61 consecutively treated patients. There was no data available on orthodontic results for 2 patients. In only 8 patients a compromise for the predetermined orthodontic goal had to be considered. Premature removal of the OBA due to infection of the soft tissues or mobility of the OBA, non compliance to the orthodontic treatment, poor oral hygiene, or the orthodontists inexperience regarding this treatment modality were mentioned as possible reasons for not achieving a completely satisfying orthodontic treatment result. Contraindications for using TAD’s include problems of healing, compromised immune defense, bleeding disorders or inadequate oral hygiene. (42, 61)

A recent systematic review of Schätzle et al. stated an average success rate of 92.7% based on 7 clinical studies with a total of 586 plate-type anchorage devices and 406 patients. (46) Cornelis et al. described in their prospective study of a large patient sample with 200 OBA’s a success rate of 92.5%. (78) Currently the literature doesn’t provide many long-term prospective studies with a large patient sample evaluating a series of different variables in relation to the success of OBA’s. (41, 75, 78) A direct comparison of the failure rates of different studies is difficult because of the differences in study design, screw and/or plate design, and insertion technique.

The 2-year outcome audit of Mommaerts et al. in 2005 was a prospective clinical registry reporting a failure rate of 8.6% for 23 OBA’s, which was a small sample to provide full evidence-based conclusions. In order to try to decrease the number of failures several changes in the hardware were introduced. (75) The base plate was roughened by etching and
sandblasting, since motion seems to appear beneath smooth plates under relatively low physiological loads.\((130, 131)\) Reduction in height of the pentagon-shaped screw heads to prevent piercing of the soft tissues and bending the neck of the connection bar into a bayonet shape was also introduced to reduce circumference of the portion piercing the gingiva and to facilitate cleaning of the posterior part of the connection bar. This prospective registry reports 98 successful OBA’s representing a success rate of 93.3%. Seven OBA’s were removed prematurely. The reasons for premature removal of the TAD were persisting infection without mobility in 3 cases, persisting infection in combination with severe mobility of the anchorage device in 2 cases. In one case there was no sign of infection, only increased mobility of the OBA prior to orthodontic loading. According to Veziroglu et al. the stability of plate-type anchorage devices depends on the stresses and strains imposed on the plate by the screw heads.\((117)\) If the bone under the plate or around the screws resorbs over time because of improper plate adaptation or due to blood flow inhibition in the cortical bone through excessive compression of the rib surface of the plate, an active force on the bone around the screws may occur. This may cause loosening of the screw(s) in addition to cortical bone resorption induced by excessive pressure and/or the rotation of the other screw(s), both of which impair the stability of the plate.\((117, 132)\) Thus, to ensure a good primary stability of the TAD over tightening of the fixation screws should be avoided and excellent passive adaptation of the plate to the anatomical bony structure is necessary to avoid excessive forces to the bone.\((79)\) Chen et al. stated that it is probably more likely that the miniscrew-bone interface rather than the miniplates themselves will expect critical failure.\((91)\)

The failure rate of the OBA’s in this registry was statistically higher in the mandible \((p = 0.024)\) although most failures were hypothetically expected to occur in the maxilla. It is well known that the buccal cortical bone of the maxilla is thinner and so less retentive than that of the mandible, therefore it could be assumed that the success rate in the mandible would be higher. Chen et al. confirmed this hypothesis, describing a higher failure rate in the maxilla than in the mandible.\((91)\) Several studies contradicted the hypothesis by describing a higher failure rate in the mandible.\((41, 42, 47, 68, 78)\) The low success rate in this region might be due to surgical mediated stress such as overheating of the bone due to drilling when harder bone is encountered.\((47, 63)\) The external cortical bone in the anterior lower jaw is thicker, particularly at the external oblique line and in the symphysis area, which has a thickness of up to 3 mm.\((98, 99)\) According to Tsunori et al. the mandibular cortical bone thickness ranges
from 1.1 mm to 3.7 mm depending on the location in the mandible.\(^{(100)}\) In this denser cortical bone, there is greater chance of generating heat above 47°C, which is the critical temperature for causing bone damage.\(^{(101, 102)}\) Other plausible reasons for a higher failure rate in the lower jaw, reported by several authors, is the low level of attached gingiva.\(^{(43, 63, 76)}\) It is important to limit mucous membrane movement close to the bone anchor. Non-keratinized emergence sites enhances mechanical soft tissue irritation which contributes to the occurrence of infection and plate mobility.\(^{(41, 68)}\) It is well known that inflammation of the peri-implant tissue causes peri-implant bone loss, which can lead to implant mobility.\(^{(105-107)}\) Takaki et al. described in their clinical study of temporary anchorage devices that inflammation of the peri-implant tissues occurred at a significantly higher rate in plate-type than in screw-type anchorage devices and that inflammation frequencies depended on the degree of mucosal penetration.\(^{(47)}\) Furthermore occlusal and masticatory forces on the OBA should be avoided at all times. According to Sugawara et al., there are 3 features that must be controlled to prevent movement of the OBA’s: bite force, bone alignment and implantation technique.\(^{(119)}\) Mommaerts et al. suggested an approach to prevent patients from chewing heavily on the OBA by placing it after an initial phase of orthodontic alignment.\(^{(36)}\)

We noticed a significantly higher failure rate (\(p = 0.034\)) of the OBA’s positioned anteriorly than those located posteriorly. Six out of 7 failed OBA’s were situated anteriorly. In our study only 5 of 66 OBA’s in the mandible were located posteriorly and the only failed OBA in a posterior location was already mobile prior to orthodontic loading. This could be due to lack of primary stability of the TAD, poor oral hygiene and the surgical placement difficulty of the anatomical location. This contradicts the findings of Chen et al. who stated that implants in the posterior mandible were more prone to failure mainly due the shallow buccal vestibule with little attached gingiva.\(^{(41)}\) Choi et al. claimed a low success rate in the mandibular body region.\(^{(68)}\) This finding was confirmed by Takaki et al. \(^{(47)}\) describing a higher success rate in the zygomatic buttress region (98%) than the mandibular body region (85%).

A very important question in the use of skeletal anchorage is when to start the loading. In the present study the time of loading, immediate or delayed, didn’t influence the success rate of the OBA’s. The literature reports mostly relatively short healing periods ranging from 6 weeks to immediate loading.\(^{(25, 26, 88, 116)}\) De Clerck et al. indicated a healing period of 2-
4 weeks before orthodontic loading to allow the soft tissues to heal. (115) Chen et al. concluded from their study that duration of healing is a significant factor for success of a TAD. (45) Avoidance of loading until after 3 weeks of healing when primary stability of the TAD is being established cannot be overemphasized even though osseointegration is not required. However these results are in contrast with the outcomes of other studies. The timing of loading was not related to the success rate according to Kuroda et al. (43) Moreover Miyawaki et al. claims that the number of days from implantation to force application was not associated with stability and that immediate loading of a screw-type implant anchor is possible if the applied force is less than 2 N. (44) Miniscrews do not osseointegrate while their anchorage stability results from mechanical interlock which eliminates the need for a waiting period before force application and permits easy removal. (25, 29-31) On the other hand, because miniscrews are not osseointegrated, their anchorage potential is most likely influenced by the quality and quantity of bone into which they are placed. (109)

The young age group exhibited more failures with a significance of \( p = 0.02 \) in this study. Six out of 7 failed OBA’s were placed in young patients (<16 yrs). In addition screw failure was more often situated in the mandible of the young age group (\( p = 0.002 \)). Loosening of all fixation screws occurred in 28.6% of all screw failures leading to the loss of 4 OBA’s. Albeit most studies reported the factor age not to be a significant variable. (41, 43, 44) Cornelis et al. mentions a higher failure rate due to mobility in growing patients than in adults. (78) Although their surgeons were always instructed to place the attachment arm penetrating the tissue at the mucogingival junction, this might be more difficult in younger patients, when alveolar height tends to be shallow, width of attached gingiva is less, and access is restricted. Another study confirmed our findings suggesting that TAD’s placed in young patients were at a significantly greater risk of failure due to less bone density and thickness of the cortical bone. (42) When analyzing the literature, the question that applies to all types of skeletal anchorage is the point of insertion with adequate bone potential, a factor of particular relevance in the cortical area. (83-85) The best approach for ensuring biomechanical strength is actual contact with mature lamellar bone. (84, 86) In young patients the level of maturity isn’t yet reached which might explain the higher failure rate in this group. In this study a higher failure rate, although not significant, of coronal fixation screws (43%) in comparison to the middle (21.4%) or the apical screw was noticed. Veziroglu et al. explained that stress
can directly affect the screws, especially the screw that is closest to the force application unit, and may impair screw stability.\(^{(117)}\)

None of the other variables such as complications, screw length, type of force application tool, or gender presented any statistical correlation, although a much higher failure rate in female patients was observed. Other studies also noticed this observation, however statistically non significant.\(^{(68, 69)}\) The diameter of the fixation screws in this study is 2.3 mm. The literature confirms that an approximately twofold increased failure rate was identified for miniscrews with a diameter of 1.2 mm compared with miniscrews with a diameter of 2 mm or more.\(^{(44, 46)}\) No statistical correlation was found between orthodontic indication and complications nor between orthodontic indication and success. The main orthodontic indication in this study were closing diastemas (64.2\%), followed by proclination, retroclination and intrusion.

The clinical observations at time of removal of the bone anchor revealed mild to moderate infection of the surrounding tissues in 4 OBA’s of which only 3 had to be removed before the end of the orthodontic treatment. A combination of infection and plate mobility was detected in 6 OBA’s of which only 2 failed. Mobility of the anchor without infection was observed in 4 cases of which 2 had to be removed prematurely. Several studies reported that, although the soft tissues surrounding the miniplates at the transmucosal area showed slight inflammatory changes, most miniplates used for orthodontic anchorage remained stable throughout their use.\(^{(39, 120)}\) In addition, some miniplates showed increased mobility without infection but remained stationary throughout orthodontic loading which was also noticed by Choi et al. The most frequently cited cause of loss was infection.\(^{(44, 88, 133)}\) Sugawara and Nishimura reported that infection occurs in about 10\% of patients.\(^{(68, 108)}\) Positioning of anchorage elements outside the dental arch fairly often leads to discomfort and more difficult care.\(^{(88)}\) Mild infection can be controlled by antiseptic mouthwash and careful brushing techniques. In general the literature insists on the extreme importance of oral hygiene for a higher success rate of TAD’s. Sato et al. suggested that the environment in crevices around titanium orthodontic anchor plates is anaerobic and supports anaerobic growth of bacteria, which may trigger inflammation in the tissues around the plates. Therefore, orthodontic treatment with titanium anchor plates requires strict self care and regular professional plaque control in order to prevent infection.\(^{(90)}\)
Gingiva recession uncovering 1 or 2 fixation screws was a rare clinical complication seen in 5 cases. This recession probably derives from soft tissue irritation due to emergence of the connection arm through non-keratinized gingiva and/or poor oral hygiene. A remarkable phenomenon at time of removal was bone overgrowth in 10 cases (9,5%), covering the bone plate and/or fixation screws in the apical region, always in the mandible and only in the young age group (Fig. 7). This might complicate removal of the TAD but mostly it was easily chipped off. Cornelis et al. also mentioned this observation.(39) In their study, bone covering 25% or more of the plate was reported for more than 1 in 10 patients, but it did not seem to be correlated with the location of the miniplate or with the age of the patient. In our study there seemed to be a correlation with the location and the age of the patient although not significant. The reason why this phenomenon happens unequally in patients is unexplained. A possible reason for the bone overgrowth happening in the young age group is a high level of bone remodeling due to their high growth potential. In 72.4 % of the OBA’s none of the previously stated clinical observations were detected.

Figure 7: Bone overgrowth is clearly visible on the fixation plate of the OBA. In this case removal of the miniplate was difficult which explains the breakage of the plate through torsional force and the imprints of a removal instrument on the OBA. (Source: Prof. Dr. Mommaerts)
VIII. Conclusion

According to the results of this study the use of OBA’s is a reliable treatment modality to obtain absolute orthodontic anchorage. Immediate loading of an OBA doesn’t generate more failures than delayed loading. Age, jaw and anterior position seem to play an important role in the success of OBA’s.
IX. References

A prospective study of an orthodontic bone anchor  
Valerie Nols


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Valerie Nols


X. Bijlage


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Valerie Nols