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Data Integrity

This chapter explains how integrity constraints enforce the business rules associated with a database and prevent the entry of invalid information into tables.

This chapter contains the following sections:

- Introduction to Data Integrity
- Types of Integrity Constraints
- States of Integrity Constraints

See Also: "Overview of Tables" on page 2-6

Introduction to Data Integrity

Business rules specify conditions and relationships that must always be true or must always be false. For example, each company defines its own policies about salaries, employee numbers, inventory tracking, and so on. It is important that data maintain **data integrity**, which is adherence to these rules, as determined by the database administrator or application developer.

Techniques for Guaranteeing Data Integrity

When designing a database application, developers have various options for guaranteeing the integrity of data stored in the database. These options include:

- Enforcing business rules with triggered stored database procedures, as described in "Overview of Triggers" on page 8-16
- Using stored procedures to completely control access to data, as described in "Introduction to Server-Side Programming" on page 8-1
- Enforcing business rules in the code of a database application
- Using Oracle Database **integrity constraints**, which are rules defined at the column or object level that restrict values in the database

This chapter explains the basic concepts of integrity constraints.

Advantages of Integrity Constraints

An integrity constraint is a **schema object** that is created and dropped using SQL. To enforce data integrity, use integrity constraints unless it is not possible. Advantages of integrity constraints over alternatives for enforcing data integrity include:

- Declarative ease

Because you define integrity constraints using SQL statements, no additional programming is required when you define or alter a table. The SQL statements are easy to write and eliminate programming errors.

- Centralized rules

  Integrity constraints are defined for tables and are stored in the **data dictionary** (see "Overview of the Data Dictionary" on page 6-1). Thus, data entered by all applications must adhere to the same integrity constraints. If the rules change at the table level, then applications need not change. Also, applications can use metadata in the data dictionary to immediately inform users of violations, even before the database checks the SQL statement.

- Flexibility when loading data

  You can disable integrity constraints temporarily to avoid performance overhead when loading large amounts of data. When the data load is complete, you can re-enable the integrity constraints.

See Also:

- *Oracle Database 2 Day Developer's Guide* and *Oracle Database 2 Day Developer's Guide* to learn how to maintain data integrity
- *Oracle Database 2 Day DBA*and *Oracle Database Administrator's Guide* to learn how to manage integrity constraints

Types of Integrity Constraints

Oracle Database enables you to apply constraints both at the table and column level. A constraint specified as part of the definition of a column or attribute is called an **inline** specification. A constraint specified as part of the table definition is called an **out-of-line** specification.

The term **key** is used in the definitions of several types of integrity constraints. A key is the column or set of columns included in the definition of certain types of integrity constraints. Keys describe the relationships between the tables and columns of a relational database. Individual values in a key are called **key values**.

Table 5–1 describes the types of constraints. Each can be specified either inline or out-of-line, except for `NOT NULL`, which must be inline.

Table 5–1 Types of Constraints

Constraint Type	Description	See Also
`NOT NULL`	Allows or disallows inserts or updates of rows containing a **null** in a specified column.	"NOT NULL Integrity Constraints" on page 5-3
Unique key	Prohibits multiple rows from having the same value in the same column or combination of columns but allows some values to be null.	"Unique Constraints" on page 5-3
Primary key	Combines a `NOT NULL` constraint and a unique constraint. It prohibits multiple rows from having the same value in the same column or combination of columns and prohibits values from being null.	"Primary Key Constraints" on page 5-5

Table 5–1 (Cont.) Types of Constraints

Constraint Type	Description	See Also
Foreign key	Designates a column as the foreign key and establishes a relationship between the foreign key and a primary or unique key, called the **referenced key**.	"Foreign Key Constraints" on page 5-6
Check	Requires a database value to obey a specified condition.	"Check Constraints" on page 5-10
REF	Dictates types of data manipulation allowed on values in a REF column and how these actions affect dependent values. In an object-relational database, a built-in data type called a REF encapsulates a reference to a row object of a specified object type. Referential integrity constraints on REF columns ensure that there is a row object for the REF.	*Oracle Database Object-Relational Developer's Guide* to learn about REF constraints

See Also:

- "Overview of Tables" on page 2-6
- *Oracle Database SQL Language Reference* to learn more about the types of constraints

NOT NULL Integrity Constraints

A NOT NULL constraint requires that a column of a table contain no null values. A **null** is the absence of a value. By default, all columns in a table allow nulls.

NOT NULL constraints are intended for columns that must not lack values. For example, the hr.employees table requires a value in the last_name column. An attempt to insert an employee row without a last name generates an error:

```
SQL> INSERT INTO hr.employees (employee_id, last_name) values (999, 'Smith');
.
.
.
ERROR at line 1:
ORA-01400: cannot insert NULL into ("HR"."EMPLOYEES"."LAST_NAME")
```

You can only add a column with a NOT NULL constraint if the table does not contain any rows or if you specify a default value.

See Also:

- *Oracle Database 2 Day Developer's Guide* for examples of adding NOT NULL constraints to a table
- *Oracle Database SQL Language Reference* for restrictions on using NOT NULL constraints
- *Oracle Database Advanced Application Developer's Guide* to learn when to use the NOT NULL constraint

Unique Constraints

A **unique key constraint** requires that every value in a column or set of columns be unique. No rows of a table may have duplicate values in a column (the **unique key**) or set of columns (the **composite unique key**) with a unique key constraint.

> **Note:** The term **key** refers only to the columns defined in the integrity constraint. Because the database enforces a unique constraint by implicitly creating or reusing an **index** on the key columns, the term **unique key** is sometimes incorrectly used as a synonym for **unique key constraint** or **unique index**.

Unique key constraints are appropriate for any column where duplicate values are not allowed. Unique constraints differ from primary key constraints, whose purpose is to identify each table row uniquely, and typically contain values that have no significance other than being unique. Examples of unique keys include:

- A customer phone number, where the primary key is the customer number
- A department name, where the primary key is the department number

As shown in Example 2–1 on page 2-8, a unique key constraint exists on the `email` column of the `hr.employees` table. The relevant part of the statement is as follows:

```
CREATE TABLE employees
    ( ...
    , email          VARCHAR2(25)
       CONSTRAINT    emp_email_nn  NOT NULL ...
    , CONSTRAINT     emp_email_uk  UNIQUE (email) ... );
```

The `emp_email_uk` constraint ensures that no two employees have the same email address, as shown in Example 5–1.

Example 5–1 Unique Constraint

```
SQL> SELECT employee_id, last_name, email FROM employees WHERE email = 'PFAY';

EMPLOYEE_ID LAST_NAME                 EMAIL
----------- ------------------------- -------------------------
        202 Fay                       PFAY

SQL> INSERT INTO employees (employee_id, last_name, email, hire_date, job_id)
  1  VALUES (999,'Fay','PFAY',SYSDATE,'ST_CLERK');
.
.
.
ERROR at line 1:
ORA-00001: unique constraint (HR.EMP_EMAIL_UK) violated
```

Unless a `NOT NULL` constraint is also defined, a null always satisfies a unique key constraint. Thus, columns with both unique key constraints and `NOT NULL` constraints are typical. This combination forces the user to enter values in the unique key and eliminates the possibility that new row data conflicts with existing row data.

> **Note:** Because of the search mechanism for unique key constraints on multiple columns, you cannot have identical values in the non-null columns of a partially null composite unique key constraint.

See Also:

- "Unique and Nonunique Indexes" on page 3-4
- *Oracle Database 2 Day Developer's Guide* for examples of adding `UNIQUE` constraints to a table

Primary Key Constraints

In a **primary key constraint**, the values in the group of one or more columns subject to the constraint uniquely identify the row. Each table can have one **primary key**, which in effect names the row and ensures that no duplicate rows exist.

A primary key can be natural or a surrogate. A **natural key** is a meaningful identifier made of existing attributes in a table. For example, a natural key could be a postal code in a lookup table. In contrast, a **surrogate key** is a system-generated incrementing identifier that ensures uniqueness within a table. Typically, surrogate keys are generated by a **sequence**.

The Oracle Database implementation of the primary key constraint guarantees that the following statements are true:

- No two rows have duplicate values in the specified column or set of columns.
- The primary key columns do not allow nulls.

A typical situation calling for a primary key is the numeric identifier for an employee. Each employee must have a unique ID. A employee must be described by one and only one row in the `employees` table.

Example 5–1 indicates that an existing employee has the employee ID of 202, where the employee ID is the primary key. The following example shows an attempt to add an employee with the same employee ID and an employee with no ID:

```
SQL> INSERT INTO employees (employee_id, last_name, email, hire_date, job_id)
  1  VALUES (202,'Chan','ICHAN',SYSDATE,'ST_CLERK');
.
.
.
ERROR at line 1:
ORA-00001: unique constraint (HR.EMP_EMP_ID_PK) violated

SQL> INSERT INTO employees (last_name) VALUES ('Chan');
.
.
.
ERROR at line 1:
ORA-01400: cannot insert NULL into ("HR"."EMPLOYEES"."EMPLOYEE_ID")
```

The database enforces primary key constraints with an **index**. Usually, a primary key constraint created for a column implicitly creates a unique index and a `NOT NULL` constraint. Note the following exceptions to this rule:

- In some cases, as when you create a primary key with a **deferrable constraint**, the generated index is not unique.

> **Note:** You can explicitly create a unique index with the `CREATE UNIQUE INDEX` statement.

- If a usable index exists when a primary key constraint is created, then the constraint reuses this index and does not implicitly create a new one.

By default the name of the implicitly created index is the name of the primary key constraint. You can also specify a user-defined name for an index. You can specify storage options for the index by including the `ENABLE` clause in the `CREATE TABLE` or `ALTER TABLE` statement used to create the constraint.

> **See Also:** *Oracle Database 2 Day Developer's Guide* and *Oracle Database Advanced Application Developer's Guide* to learn how to add primary key constraints to a table

Foreign Key Constraints

Whenever two tables contain one or more common columns, Oracle Database can enforce the relationship between the two tables through a **foreign key constraint**, also called a **referential integrity constraint**. The constraint requires that for each value in the column on which the constraint is defined, the value in the other specified other table and column must match. An example of a referential integrity rule is an employee can work for only an existing department.

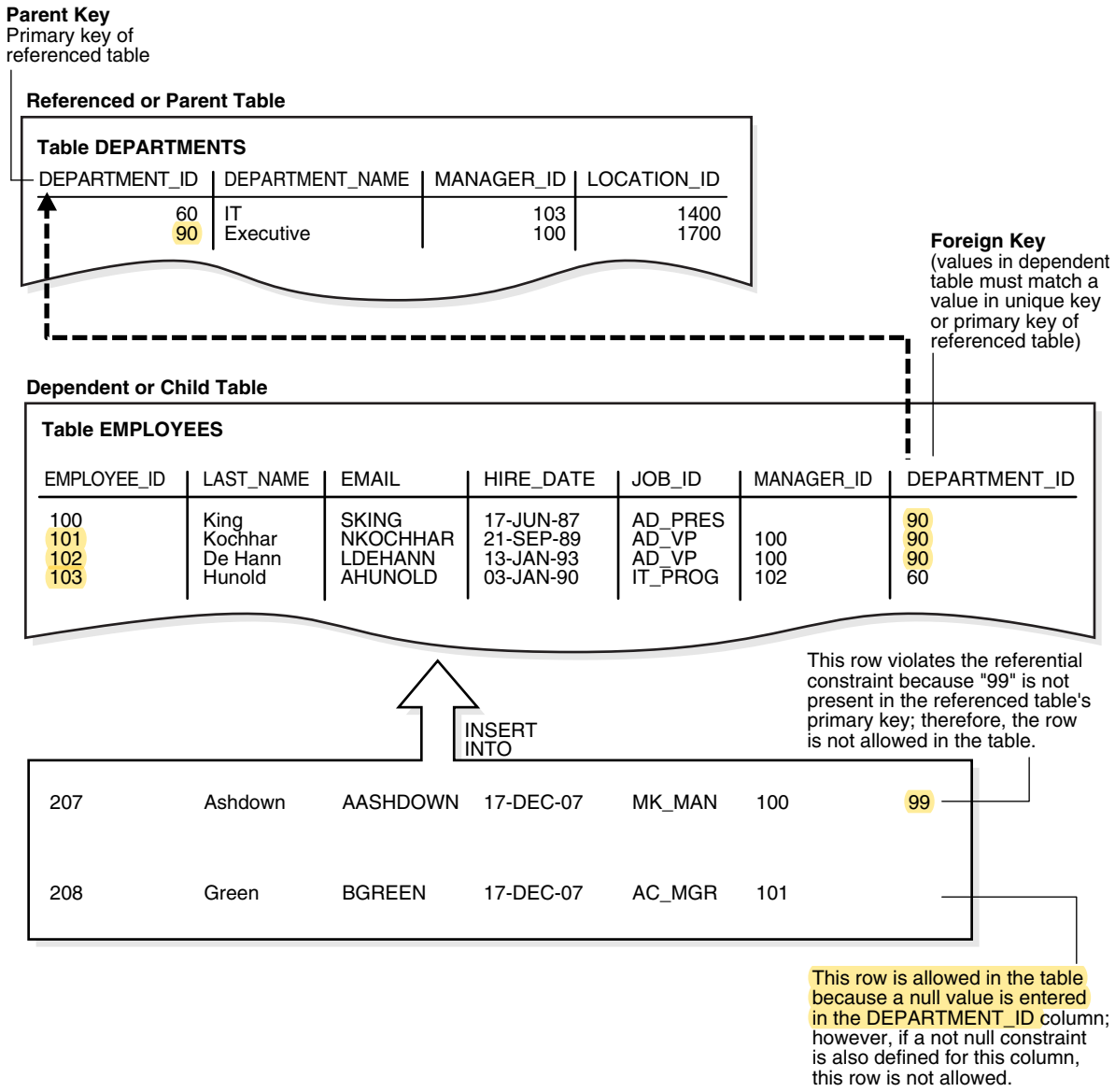
Table 5–2 lists terms associated with referential integrity constraints.

Table 5–2 Referential Integrity Constraint Terms

Term	Definition
Foreign key	The column or set of columns included in the definition of the constraint that reference a referenced key. For example, the `department_id` column in `employees` is a foreign key that references the `department_id` column in `departments`. Foreign keys may be defined as multiple columns. However, a **composite foreign key** must reference a composite primary or unique key with the same number of columns and the same data types. The value of foreign keys can match either the referenced primary or unique key value, or be null. If any column of a composite foreign key is null, then the non-null portions of the key do not have to match any corresponding portion of a parent key.
Referenced key	The unique key or primary key of the table referenced by a foreign key. For example, the `department_id` column in `departments` is the referenced key for the `department_id` column in `employees`.
Dependent or child table	The table that includes the foreign key. This table is dependent on the values present in the referenced unique or primary key. For example, the `employees` table is a child of `departments`.
Referenced or parent table	The table that is referenced by the foreign key of the child table. It is this table's referenced key that determines whether specific inserts or updates are allowed in the child table. For example, the `departments` table is a parent of `employees`.

Figure 5–1 shows a foreign key on the `employees.department_id` column. It guarantees that every value in this column must match a value in the `departments.department_id` column. Thus, no erroneous department numbers can exist in the `employees.department_id` column.

Figure 5–1 Referential Integrity Constraints



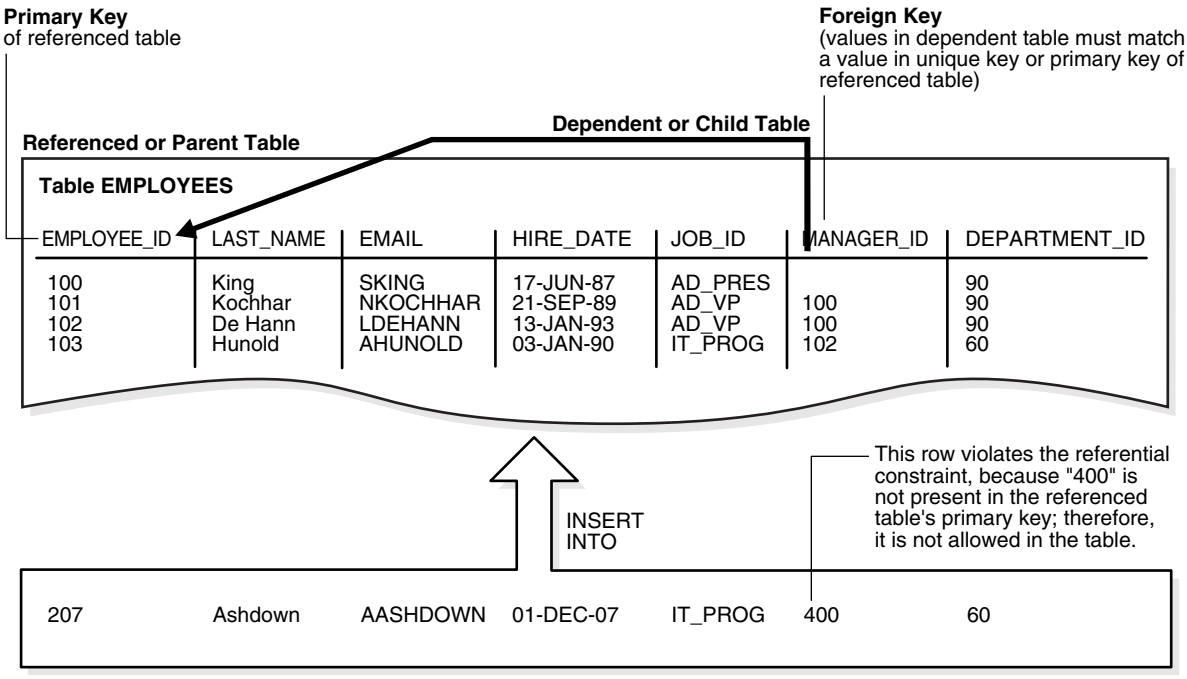
See Also: *Oracle Database 2 Day Developer's Guide* and *Oracle Database Advanced Application Developer's Guide* to learn how to add foreign key constraints to a table

Self-Referential Integrity Constraints

Figure 5–2 shows a **self-referential integrity constraint**. In this case, a foreign key references a parent key in the same table.

In Figure 5–2, the referential integrity constraint ensures that every value in the `employees.manager_id` column corresponds to an existing value in the `employees.employee_id` column. For example, the manager for employee 102 must exist in the `employees` table. This constraint eliminates the possibility of erroneous employee numbers in the `manager_id` column.

Figure 5–2 Single Table Referential Constraints



Nulls and Foreign Keys

The relational model permits the value of foreign keys to match either the referenced primary or unique key value, or be null. For example, a user could insert a row into `hr.employees` without specifying a department ID.

If any column of a composite foreign key is null, then the non-null portions of the key do not have to match any corresponding portion of a parent key.

Parent Key Modifications and Foreign Keys

The relationship between foreign key and parent key has implications for deletion of parent keys. For example, if a user attempts to delete the record for this department, then what happens to the records for employees in this department?

When a parent key is modified, referential integrity constraints can specify the following actions to be performed on dependent rows in a child table:

- No action on deletion or update

  In the normal case, users cannot modify referenced key values if the results would violate referential integrity. For example, if `employees.department_id` is a foreign key to `departments`, and if employees belong to a particular department, then an attempt to delete the row for this department violates the constraint.

- Cascading deletions

  A deletion **cascades** (`DELETE CASCADE`) when rows containing referenced key values are deleted, causing all rows in child tables with dependent foreign key values to also be deleted. For example, the deletion of a row in `departments` causes rows for all employees in this department to be deleted.

- Deletions that set null

  A deletion **sets null** (`DELETE SET NULL`) when rows containing referenced key values are deleted, causing all rows in child tables with dependent foreign key

values to set those values to null. For example, the deletion of a department row sets the `department_id` column value to null for employees in this department.

Table 5–3 outlines the DML statements allowed by the different referential actions on the key values in the parent table, and the foreign key values in the child table.

Table 5–3 DML Statements Allowed by Update and Delete No Action

DML Statement	Issued Against Parent Table	Issued Against Child Table
`INSERT`	Always OK if the parent key value is unique	OK only if the foreign key value exists in the parent key or is partially or all null
`UPDATE NO ACTION`	Allowed if the statement does not leave any rows in the child table without a referenced parent key value	Allowed if the new foreign key value still references a referenced key value
`DELETE NO ACTION`	Allowed if no rows in the child table reference the parent key value	Always OK
`DELETE CASCADE`	Always OK	Always OK
`DELETE SET NULL`	Always OK	Always OK

Note: Other referential actions not supported by `FOREIGN KEY` integrity constraints of Oracle Database can be enforced using database triggers. See "Overview of Triggers" on page 8-16.

See Also: *Oracle Database SQL Language Reference* to learn about the `ON DELETE` clause

Indexes and Foreign Keys

As a general rule, Oracle recommends indexing foreign keys in heap-organized tables. An exception for nonpartitioned tables is when the matching unique or primary key is never updated or deleted.

Note: Additional considerations apply to non-heap data structures such as index-organized tables and table clusters.

Indexing the foreign keys in child tables provides the following benefits:

- Prevents a full table lock on the child table. Instead, the database acquires a row lock on the index.
- Removes the need for a **full table scan** of the child table. As an illustration, assume that a user removes the record for department 10 from the `departments` table. If `employees.department_id` is not indexed, then the database must scan `employees` to determine whether any employees exist in department 10.

See Also: "Locks and Foreign Keys" on page 9-21 and "Overview of Indexes" on page 3-1

Check Constraints

A **check constraint** on a column or set of columns requires that a specified **condition** be true or unknown for every row. If DML results in the condition of the constraint evaluating to false, then the SQL statement is rolled back.

The chief benefit of check constraints is the ability to enforce very specific integrity rules. For example, you could use check constraints to enforce the following rules in the `hr.employees` table:

- The `salary` column must not have a value greater than 10000.
- The `commission` column must have a value that is not greater than the salary.

The following example creates a maximum salary constraint on `employees` and demonstrates what happens when a statement attempts to insert a row containing a salary that exceeds the maximum:

```
SQL> ALTER TABLE employees ADD CONSTRAINT max_emp_sal CHECK (salary < 10001);
SQL> INSERT INTO employees (employee_id,last_name,email,hire_date,job_id,salary)
  1  VALUES (999,'Green','BGREEN',SYSDATE,'ST_CLERK',20000);
.
.
.
ERROR at line 1:
ORA-02290: check constraint (HR.MAX_EMP_SAL) violated
```

A single column can have multiple check constraints that reference the column in its definition. For example, the `salary` column could have one constraint that prevents values over 10000 and a separate constraint that prevents values less than 500.

If multiple check constraints exist for a column, then you must design them so that their aims do not conflict. No order of evaluation of the conditions can be assumed. The database does not verify that check conditions are not mutually exclusive.

> **See Also:** *Oracle Database SQL Language Reference* to learn about restrictions for check constraints

States of Integrity Constraints

As part of constraint definition, you can specify how and when Oracle Database should enforce the constraint, thereby determining the **constraint state**.

Checks for Modified and Existing Data

The database enables you to specify whether a constraint applies to existing data or future data. If a constraint is **enabled**, then the database checks new data as it is entered or updated. Data that does not conform to the constraint cannot enter the database. For example, enabling a `NOT NULL` constraint on `employees.department_id` guarantees that every future row has a department ID. If a constraint is **disabled**, then the table can contain rows that violate the constraint.

You can set constraints to **validate** (`VALIDATE`) or not validate (`NOVALIDATE`) existing data. If `VALIDATE` is specified, then existing data must conform to the constraint. For example, enabling a `NOT NULL` constraint on `employees.department_id` and setting it to `VALIDATE` checks that every existing row has a department ID. If `NOVALIDATE` is specified, then existing data need not conform to the constraint.

The behavior of `VALIDATE` and `NOVALIDATE` always depends on whether the constraint is enabled or disabled. Table 5–4 summarizes the relationships.

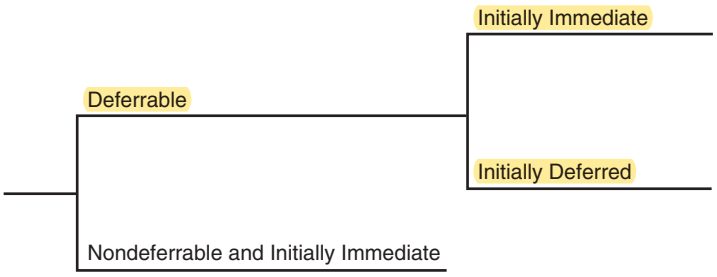
Table 5–4 Checks on Modified and Existing Data

Modified Data	Existing Data	Summary
`ENABLE`	`VALIDATE`	Existing and future data must obey the constraint. An attempt to apply a new constraint to a populated table results in an error if existing rows violate the constraint.
`ENABLE`	`NOVALIDATE`	The database checks the constraint, but it need not be true for all rows. Thus, existing rows can violate the constraint, but new or modified rows must conform to the rules.
`DISABLE`	`VALIDATE`	The database disables the constraint, drops its index, and prevents modification of the constrained columns.
`DISABLE`	`NOVALIDATE`	The constraint is not checked and is not necessarily true.

See Also: *Oracle Database SQL Language Reference* to learn about constraint states

Deferrable Constraints

Every constraint is either in a **not deferrable** (default) or **deferrable** state. This state determines when Oracle Database checks the constraint for validity. The following graphic depicts the options for deferrable constraints.



Nondeferrable Constraints

If a constraint is not deferrable, then Oracle Database never defers the validity check of the constraint to the end of the transaction. Instead, the database checks the constraint at the end of each statement. If the constraint is violated, then the statement rolls back.

For example, assume that you create a nondeferrable `NOT NULL` constraint for the `employees.last_name` column. If a user attempts to insert a row with no last name, then the database immediately rolls back the statement because the `NOT NULL` constraint is violated. No row is inserted.

Deferrable Constraints

A **deferrable constraint** permits a transaction to use the `SET CONSTRAINT` clause to defer checking of this constraint until a `COMMIT` statement is issued. If you make changes to the database that might violate the constraint, then this setting effectively lets you disable the constraint until all the changes are complete.

You can set the default behavior for when the database checks the deferrable constraint. You can specify either of the following attributes:

- `INITIALLY IMMEDIATE`

  The database checks the constraint immediately after each statement executes. If the constraint is violated, then the database rolls back the statement.

- `INITIALLY DEFERRED`

  The database checks the constraint when a `COMMIT` is issued. If the constraint is violated, then the database rolls back the transaction.

Assume that a deferrable `NOT NULL` constraint on `employees.last_name` is set to `INITIALLY DEFERRED`. A user creates a transaction with 100 `INSERT` statements, some of which have null values for `last_name`. When the user attempts to commit, the database rolls back all 100 statements. However, if this constraint were set to `INITIALLY IMMEDIATE`, then the database would not roll back the transaction.

If a constraint causes an action, then the database considers this action as part of the statement that caused it, whether the constraint is deferred or immediate. For example, deleting a row in `departments` causes the deletion of all rows in `employees` that reference the deleted department row. In this case, the deletion from `employees` is considered part of the `DELETE` statement executed against `departments`.

> **See Also:** *Oracle Database SQL Language Reference* for information about constraint attributes and their default values

Examples of Constraint Checking

Some examples may help illustrate when Oracle Database performs the checking of constraints. Assume the following:

- The `employees` table has the structure shown in Figure 5–2 on page 5-8.
- The self-referential constraint makes entries in the `manager_id` column dependent on the values of the `employee_id` column.

Insertion of a Value in a Foreign Key Column When No Parent Key Value Exists

Consider the insertion of the first row into the `employees` table. No rows currently exist, so how can a row be entered if the value in the `manager_id` column cannot reference any existing value in the `employee_id` column? Some possibilities are:

- A null can be entered for the `manager_id` column of the first row, if the `manager_id` column does not have a `NOT NULL` constraint defined on it.

  Because nulls are allowed in foreign keys, this row is inserted into the table.

- The same value can be entered in the `employee_id` and `manager_id` columns, specifying that the employee is his or her own manager.

  This case reveals that Oracle Database performs its constraint checking *after* the statement has been completely run. To allow a row to be entered with the same values in the parent key and the foreign key, the database must first run the statement (that is, insert the new row) and then determine whether any row in the table has an `employee_id` that corresponds to the `manager_id` of the new row.

- A multiple row `INSERT` statement, such as an `INSERT` statement with nested `SELECT` statement, can insert rows that reference one another.

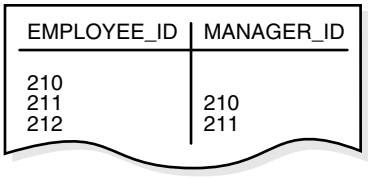
  For example, the first row might have 200 for employee ID and 300 for manager ID, while the second row has 300 for employee ID and 200 for manager. Constraint checking is deferred until the complete execution of the statement. All rows are inserted first, and then all rows are checked for constraint violations.

Default values are included as part of an `INSERT` statement before the statement is parsed. Thus, default column values are subject to all integrity constraint checking.

An Update of All Foreign Key and Parent Key Values

Consider the same self-referential integrity constraint in a different scenario. The company has been sold. Because of this sale, all employee numbers must be updated to be the current value plus 5000 to coordinate with the employee numbers of the new company. Because manager numbers are really employee numbers (see Figure 5–3), the manager numbers must also increase by 5000.

Figure 5–3 The employees Table Before Updates

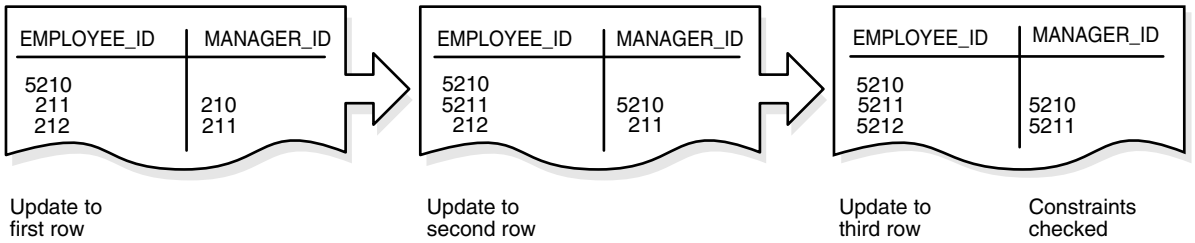


You could execute the following SQL statement to update the values:

```
UPDATE employees SET employee_id = employee_id + 5000,
  manager_id = manager_id + 5000;
```

Although a constraint is defined to verify that each `manager_id` value matches an `employee_id` value, the preceding statement is legal because the database effectively checks constraints after the statement completes. Figure 5–4 shows that the database performs the actions of the entire SQL statement before checking constraints.

Figure 5–4 Constraint Checking



The examples in this section illustrate the constraint checking mechanism during `INSERT` and `UPDATE` statements, but the database uses the same mechanism for all types of DML statements. The same mechanism is used for all types of constraints, not just self-referential constraints.

Note: Operations on a **view** or **synonym** are subject to the integrity constraints defined on the base tables.
